This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Sci 1520.119.3

Harvard College Library

THE GIFT OF

Cancelled
from
Baker Library

FOR THE

GRADUATE SCHOOL OF
BUSINESS ADMINISTRATION

SCIENCE CENTER LIBRARY

Vol. XIX January to December, 1914

JOURNAL
OF THE
WESTERN SOCIETY
OF
ENGINEERS

PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS

CHICAGO
Published by the Society
1735 Monadnock Block

Subscription Price $3.00 Per Volume
of Ten Numbers

Sci 15[illegible]
TRANSFERRED TO
HARVARD COLLEGE LIBRARY
1934

CONTENTS BY NUMBERS

Cancelled
from
Baker Library

Vol. XIX.—January-December, 1914.

NO. 1. JANUARY

Factors Determining a Reasonable Charge for Public Utility Service. M. E. Cooley 1
Testing of Horizontal Lowhead Water Turbines at Elkhart, Indiana. Lucius B. Andrus 18
The Grand Stand for the University of Chicago. Charles Hodgdon 72

Proceedings of the Society—
  Minutes of Meetings 84
  Annual Reports 86
  Octave Chanute Medal Awards 90

Address of Retiring President, Albert Reichmann 91
Address of President-elect, Edward Hervey Lee 93
Alternating Currents, S. E. Kiser 98
Book Reviews 104
Library Notes 109
Membership 112
Index to Advertisers xxii

NO. 2. FEBRUARY

Retaining Walls. J. W. Pearl 113
Manufacture of By-Product Coke. T. V. Salt 173
Moderate Capacity Outdoor High-Tension Substations. H. W. Young 204

Memorial—
  J. W. Johnson 227

Proceedings of the Society—
  Minutes of Meetings 228
  Book Reviews 229
  Library Notes 231
Index to Advertisers xxii

NO. 3. MARCH

The Necessity of Ventilation. Meyer J. Sturm 233
A Campaign to Prevent Fire. Franklin H. Wentworth 258
The Cement Gun and Its Work. Carl Weber 272

Memorials:
  Charles Edward DeCrow 316
  Adam Comstock 317
Proceedings of the Society, Minutes of Meetings 319
Book Reviews 320
Library Notes 322
Membership 324
Index to Advertisers XXII

NO. 4. APRIL

City Transportation—Subways and Railroad Terminals. Bion J. Arnold. 325
Wind Loads on Buildings. Albert Smith 369
The Making of a Technical Journal. E. J. Mehren 393

Memorials:
  Robert Strother Draper 404
  Abel O. Anderson 405

Proceedings of the Society, Minutes of Meetings.................... 406
Book Reviews 408
Library Notes 410
Membership 412
Index to Advertisers.. XXII

NO. 5. MAY

The Engineering Opportunities of Our Coal Mining Fields. Andrews Allen 413
Mining Laboratories of the University of Illinois. H. H. Stoek and E. A. Holbrook.............................. 459
Power Problems in the Steel Business. F. G. Gasche................. 487

Public Utilities.

Government Regulation of Railroads From the Investor's Standpoint. Andrew Cooke.. 503
Valuation of Public Utilities From the Railway Point of View. Samuel O. Dunn.. 507
Public Utility Regulation From the Standpoint of the Public and the Engineer. Harold Almert.............................. 516
Proceedings of the Society, Minutes of Meetings.................... 541
Book Reviews 543
Library Notes 547
Membership 548
Index to Advertisers.. XXII

NO. 6. JUNE

Types of Movable Bridges. Wilbur M. Wilson........................ 549
Topography of the Bed-Rock Under Chicago. Roderick Peattie........ 590
Electrical Inspection 612
Third Avenue Reinforced Concrete Bridge at Cedar Rapids, Iowa. Barton J. Sweatt.. 631

Memorials:

Emil Gerber, M.W.S.E.. 647
R. B. Seymour, M.W.S.E.. 649
W. D. Taylor, M.W.S.E... 650
Proceedings of the Society, Minutes of Meetings.................... 652
Book Reviews 654
Library Notes 655
Membership 656
Index to Advertisers.. XXII

NO. 7. SEPTEMBER

Panama Canal. A. S. Zinn and L. D. Cornish......................... 657
Universal Use of Electricity on the Panama Canal. D. P. Gaillard...... 685
Grading Yellow Pine Timber for Structural Purposes. A. T. North.... 706
100-Foot Length Standard 735
Midsummer Excursion to Clearing................................. 748
Book Reviews 751
Library Notes 754
Membership 756
Index to Advertisers.. XXII

NO. 8. OCTOBER

The Future Sanitary Problem of Chicago. A Symposium.............. 757
Characteristic Curves of Centrifugal Pumps. F. William Greve, Jr.... 776
Sewage Disposal Plant at Aberdeen, South Dakota. W. G. Potter...... 788
Proceedings of the Society, Minutes of Meetings.................... 806

Book Reviews 808
Library Notes 810
Membership 812
Index to Advertisers XXII

NO. 9. NOVEMBER

Permeability Tests on Gravel Concrete. Morton O. Withey........ 813
Arithmetical Machines. H. E. Goldberg........ 859
Reactions in a Three-Legged Stiff Frame With Hinged Column Bases. N. M. Stineman........ 881

Memorials:

Barnabas Schreiner 921
William H. Pratt........ 922
Proceedings of the Society. Minutes of Meetings........ 924
Book Reviews 925
Library Notes 930
Membership 932
Index to Advertisers XXII

NO. 10. DECEMBER

The Work and Some Accomplishments of the Forest Products Laboratory, Madison, Wis. Howard F. Weiss........ 933
Some Aspects of the Work of the Illinois Utilities Commission. Robert M. Feustel 965
Coon Rapids Low-Head Hydro-Electric Development on the Mississippi River Near Minneaoplis. J. W. Link........ 979
American Mining Congress. Report of 17th Annual Meeting........1016
Proceedings of the Society. Minutes of Meetings........1019
Book Reviews 1021
Library Notes 1026
Membership 1028
Index to Advertisers........XXII

FEB 24 1914

VOL. XIX, No. 1. JANUARY, 1914

JOURNAL

OF THE

WESTERN SOCIETY

OF

ENGINEERS

CONTENTS

Factors Determining a Reasonable Charge for Public Utility Service. M. E. Cooley 1
Testing of Horizontal Lowhead Water Turbines at Elkhart, Indiana. Lucius B. Andrus 18
Discussion:
By D. W. Roper, Wm. B. Jackson, R. L. Sackett, J. C. Pinney, M. G. Lloyd, L. F. Harza, and Mr. Andrus.
The Grand Stand for the University of Chicago, Charles Hodgdon.... 72
Discussion:
By J. H. Prior, W. C. Armstrong, L. J. Mensch, J. F. Brown, Wirt F. Smith, Ernest McCullough, I. F. Stern, and Mr. Hodgdon.
Proceedings of the Society—
Minutes of Meetings 64
Annual Reports 86
Octave Chanute Medal Awards 90
Address of Retiring President, Albert Reichmann 91
Address of President-elect, Edward Hervey Lee 93
Alternating Currents, S. E. Kiser 98
Book Reviews 104
Library Notes 109
Membership 112

CHICAGO

Published Monthly, Excepting July and August, by the Society,
1735 Monadnock Block.

Entered as Second-Class Matter March 2, 1896, at the Post Office at
Chicago, Ill., under Act of March 3, 1879.

Subscription Price, $3.00 per Volume of Ten Numbers.

50 Cents a Single Number.

Copyright, 1914, by the Western Society of Engineers.

WESTERN SOCIETY OF ENGINEERS

1735 Monadnock Block, Chicago, Illinois.
Phone Harrison 945.

OFFICERS FOR 1914.

President	E. H. Lee, Dearborn Station
First Vice-President	B. E. Grant, Room 207 City Hall
Second Vice-President	Ernest McCullough, 1302 Monadnock Block
Third Vice-President	G. F. Gebhardt, Armour Institute
Treasurer	C. R. Dart, Room 700, 900 Michigan Ave.
Trustee	J. G. Giaver, 1 year, 1417 Railway Exchange
Trustee	F. E. Davidson, 2 years, 1448 Monadnock Block
Trustee	H. S. Baker, 3 years, 402 City Hall

Past Presidents on the Board of Direction.

O. P. Chamberlain	106 So. La Salle St.
W. C. Armstrong	226 W. Jackson Blvd.
Albert Reichmann	72 W. Adams St.

ELECTRICAL SECTION

Executive Committee

F. J. Postel, Chairman; H. M. Wheeler, Vice-Chairman

G. T. Seely	1 year
P. B. Woodworth	2 years
E. W. Allen	3 years

BRIDGE AND STRUCTURAL SECTION.

Executive Committee

J. H. Prior	Chairman
J. W. Musham	Vice-Chairman

E. N. Layfield H. C. Lothholz I. F. Stern

HYDRAULIC, SANITARY AND MUNICIPAL SECTION

Executive Committee

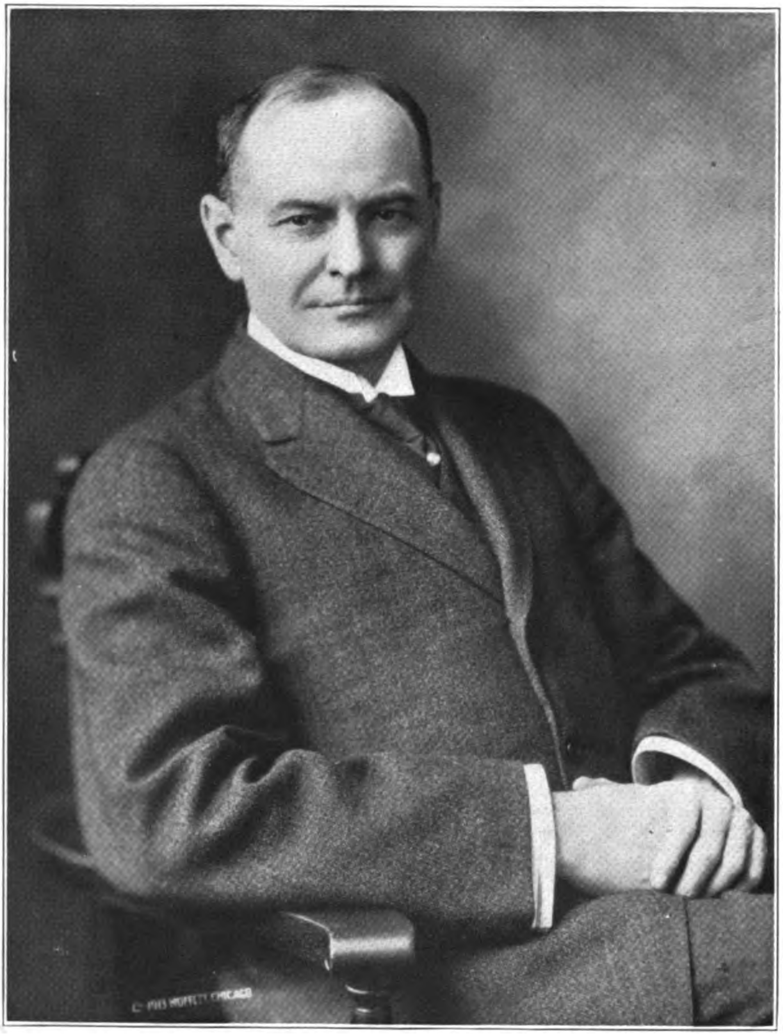
W. D. Gerber	Chairman
G. C. D. Lenth	Vice-Chairman

W. W. DeBerard Douglas Graham Langdon Pearse

Secretary............J. H. Warder

The Chanute Medals

The Board of Direction, W. S. E., desire to announce that the Octave Chanute Medals will be awarded for the most meritorious papers on Engineering subjects presented before this Society by members thereof during the year 1914.



PRESIDENT 1914
OF THE
WESTERN SOCIETY OF ENGINEERS

Journal of the
Western Society of Engineers

VOL. XIX JANUARY, 1914 No. 1

FACTORS DETERMINING A REASONABLE CHARGE FOR PUBLIC UTILITY SERVICE

An Address by M. E. Cooley at the annual dinner of the Western Society of Engineers, Hotel La Salle, Chicago, January 7, 1914.*

Probably no question of greater importance confronts our people today than the relations of the public and the public service corporations. I refer to relations of a domestic character, rather than foreign, those which affect us as a nation considered as a family in which the interests of all of its members are, or should be, intwined, interwoven, in such manner that whatever is good for one is good for another.

Naturally in treating my subject I shall have in mind ideals which may require years for their realization, but I shall hope to appeal to you with arguments based so firmly on actual facts that I shall not be accused of being academic. I shall endeavor to throw upon my subject the light of nearly fifteen years of experience in the investigation of public utility properties, and I shall hope to leave with you the impression that my views have been expressed with due regard to proper perspective. That is to say, I shall hope to avoid being accused by anyone of even *appearing* to favor one side of the question as against the other. My desire is to speak of what may be seen from the hilltop of any one who will divorce himself from the interests of either side, and try to look upon the problem with unbiased vision.

There are, of course, two sides to this question as there must be in order that any question can exist. There is the side of the public and the side of the public service corporation. Today they are wide apart. They are wide apart for one principal reason, namely, ignorance. While it may be no disgrace to be ignorant, it is disgraceful to remain ignorant when so little education is required to dispel it. The education required is not difficult; indeed, it is very simple; but the trouble is that very many of those who most need it are not willing to be educated. Various motives exist, which I will not discuss here, further than to mention that chief among them is a spirit of antagonism, akin to revenge on the part of the public, in localities where the opportunity exists for its manifestation.

---

*Dean of the College of Engineering, University of Michigan.

It is, I believe, generally considered by the officers of public service corporations that they are, or rather were, themselves responsible for the unfriendly attitude of the public toward them which is now almost general in this country. The public service corporation has in the past proceeded on the theory that the words *public service* had no particular meaning, and that like any other corporation it was at liberty, and indeed had the right, to make as much money as possible out of its business. The public service corporation has in the past ignored the fact that its right to do business is a public grant, a grant which in the very nature of it precluded others from engaging in the same business in the same locality. True, in theory, at least, others might be admitted to the field and thus create competition, but practically it has not worked out that way. Ordinarily there is not enough business for two, and even if there were, great inconvenience is likely to result; as for instance in the use of two telephone systems, two waterworks systems, and several street car systems in the same city. It is much to the advantage of the public, both in convenience and expense, to have a single utility of the different kinds serve it when that service can be had on fair terms.

What are fair terms? That is what is partly meant by the words *reasonable charge* in the title of this paper. I say *partly* meant. In the broad sense they may be synonymous. To illustrate: The service rendered by a public service corporation may be very poor without any good excuse for it. In such a case a reasonable charge would be less than when the service was entirely satisfactory. Careless or unintelligent management, or a desire to increase the dividend rate, would lead to this result. Again, the service rendered may be very poor and yet be the best possible and keep the business alive; that is, were the rates higher a better service could be rendered. This may be found in small towns where the extent of the business will not support anything better. Further, the service may be very unsatisfactory and still be the best possible to render regardless of rates; that is, physical conditions may limit the ability to render satisfactory service. This may be found in large cities, an example being a street railroad system which can not be extended except by building elevated or underground systems.

Fair terms, then, means fair service, or the best possible under the conditions, to the public on the one hand, and a reasonable charge for that service to the corporation on the other hand. They are, or should be, the two members of an equation which are equal to each other. Like an equation, given the service demanded and certain other factors involved, the fair rate, or the reasonable charge, can be readily determined. It is these factors we come now to consider. They embrace, *first,* the capital investment upon which the interest return is made either in the form of interest or dividends, or both; *second,* the operating expenses which include maintenance and repairs of all the elements of the physical property,and taxes; *third,* a depreciation fund out of which can be replaced elements of the physical property which are worn out, or have become obsolete, so that they can no longer be used economically; and, *fourth,* a sinking fund to provide for the loss of capital due to depreciation, or the difference between the cost of the property when new and when disposed of at the expiration of its franchise life. Let us take them up in order, capital investment first.

It should be understood at the outset that no capital can be made available for a public utility, or for any other business, for that matter, without a sufficient return on the money to tempt its investment in the business. Capital obeys the law of supply and demand like any commodity. Thus, if capital be invited for investment in a service which is desired by the public, then the public must expect to pay the price in the form of interest or dividends which is necessary to secure it.

However much in the past capital may have been tempted into the field without invitation in the hope of large returns, those days are rapidly disappearing; and before very long, if not now, we shall be obliged, not only to extend an invitation, but to offer inducements to bring capital to our door. Those inducements must be not only a fair return on the capital investment but a welcome guaranteed throughout a term of years. Capital may be compared with the guest in our household. While she bides with us she is entitled to the treatment accorded to a guest. She may have worn out her welcome but at the same time have become indispensable to our domestic affairs, so that we must continue to suffer her presence. We, the public, cannot invite the guest and then while she is with us slap her face; on the other hand, the guest cannot with impunity proceed to rob us once she is in our home.

There is at present a very natural distrust on the part of the public. Capital in the past having very often been self-invited, and having been at first welcomed, then tolerated, has finally worn out both welcome and toleration. The logical result, one might think, would be to get along without capital. But of course that would be impossible. Whether the utility be built and operated by the public or by a corporation, capital is necessary. It is true that for a municipally owned utility, capital may be had on more favorable terms with the security which the public can offer; but it does not follow that the service rendered *would* be had at correspondingly low rates or reasonable charges. It *could* perhaps, but the experience of the past favors the belief that such expectation would be utopian rather than practical.

The time is coming, if not already here, when it will make no difference whether capital be invested under the direct security afforded by a municipally owned utility or the more indirect security afforded by a franchise to a corporation. This time will have arrived when the public comes to understand the elements of cost, and all of them, which enter into the construction of a public utility plant. Those elements of cost are the same, or substantially the same, whether the plant be constructed by the public or by the corporation. The public must have a board intrusted with the construction and management of the utility. This board corresponds practically to the corporation's board of directors.

The board, whichever it may be, becomes the agent of the public. It makes the preliminary investigations, employs legal counsel, real estate men to procure the necessary right-of-way, conducts condemnation proceedings, obtains property consents, and attends to all matters connected with the proper launching of the project. It employs engineers to prepare the plans and specifications, invites bids, awards the contracts, and looks after the work during the construction period. It makes arrangements for the necessary funds to finance the project, the necessary working capital, and finally, after the work of construction is completed, puts the plant into operation.

Before its work has been done completely, the business must be thoroughly established, that is, converted from an inanimate to an animate condition. The earnings from operation must as speedily as possible be brought to a point where they will support all of the expenses. During the period of insufficient earnings, the deficits must be cared for. When the earnings become sufficient to meet all expenses, including interest on the cost of the property, the utility may be said to have become fully a *going concern.*

In all of this work the duties of the board or city officials representing the public or of the officers representing the corporation, have been the same. The elements of costs have been the same. The principles involved have been the same. The only difference has been one of degree on some of the items, as for instance, less difficulty possibly in securing rights-of-way, and more favorable terms in financing. But as already stated, these advantages may in the ultimate results be more *apparent* than *real.* That phase I have no intention of discussing in this paper.

The principal cause of the difference of opinion between the public and the public service corporation, as I have come to see it, lies in the failure of the public to comprehend all of the elements of cost entering into the construction of a public utility plant. Not only that but a failure also to understand all of the elements of expense which must be incurred in operating the property and maintaining its integrity, once the plant has been built and the business established. The corporation itself is only beginning to understand some of these things. Its officers intrusted with the management of the property have been obliged to make the best of things, striving on the one hand to earn the dividends called for by the stockholders, and on the other, to maintain the property so as to give satisfactory service. Without in any way excusing the corporation from its sins of the past or of the present where they still exist, the trouble is now understood by the corporation, partly at least; and it must be conceded, I think, that just at present the fault lies more with the public than with the corporation. Let us now take up the elements of cost constituting the capital investment.

It will be easier of understanding if individuals will consider themselves a party to the enterprise. Assume, for instance, that you are one of a number of men brought together to consider the building of a public utility property. What is the first step? Naturally you will all want to know whether the project is feasible. This will always involve preliminary investigations, the sounding of public sentiment to know to what extent the proposed service would be demanded, what concessions would have to be obtained in the matter of property consents and the conditions under which a franchise could be obtained. If these inquiries have resulted favorably, the next step would be to employ engineers to look over the field and make preliminary estimates of cost and determine upon the feasibility of the project. With the information thus far accumulated, the bankers must be consulted to determine whether the necessary money can be had. At this point the project may fall through as there may not be a sufficient promise of financial return to induce capital to come into the enterprise.

All of this preliminary investigation has involved expense which must be borne by someone. It may run from 0.2 to 0.5 per cent of the cost of the proposed property. In case of failure to go further it would fall upon the individuals taking part in the investigation. They have gambled and lost. But should the future promise be great enough to interest capital *mildly,* let us say, then the bankers might be induced to gamble a bit, and by being given sufficient odds in the way of discount on bonds and blocks of capital stock depending for their value on future earnings, be induced to come in. The less of gamble there may be, the less the odds demanded by the banks; but at the present time these keepers of the vital life of all business enterprises must, like the well fed trout, have bait of some form on the hook to interest them at all. Not so, however, with the rank and file who, like the hungry bullhead, bite at anything, even in the dark, if only the light of a candle be exposed to show in the faintest outline the nature of the bait. But public utility properties for the most part are not financed by the rank and file, but by bankers and trust companies. It is, therefore, a real "condition, and not a theory," which confronts the promoter when he seeks to finance a proposition.

If, finally, the preliminary work has resulted in the determination to proceed, there comes the organization of the company, the employment of legal counsel to draw up the necessary papers, the procuring of the franchises, the obtaining of the necessary property consents, the securing of the right-of-way by purchase or otherwise, the employment of engineers to make the final surveys, prepare the plans and specifications, the bidding and award of contracts. The actual work of construction then begins.

It is at this point that the public conceives the cost of the property to begin; and for the reason that the average citizen, skilled as he may be in the work of his own pursuit, has little or no knowledge of the skill required in another's pursuit. Yet this average citizen must be consulted because the project is a public utility. It furnishes him heat, light and power, transports him to his business, and provides him with other fixed necessities of life. This being so, let the condition be met, and first of all let this average citizen be educated to understand the requirements which must be met if he is to be furnished these necessities of our modern civilization. Once he understands, there will not be, so far as he is concerned, any further trouble. The average citizen is fair minded, and asks for only the square deal.

There is, however, another type of citizen who, however much explaining there may be, persists in seeing things his own way. He may be a self-appointed guardian of the people's interest; sincere enough and honest enough, but too often his zeal results in confusion of understanding, if not perniciousness. Another type belongs to the political class. He sees gain in one form or another, if he can keep alive the troubles between the public and the public service corporation.

There is no greater service to be rendered the people of our country today than that which could be rendered by the newspapers if they would but go at this matter with the idea of acquainting their readers with the facts on both sides. I mean that they should not treat the quarrels between the public and public service corporations as items of news merely, but detail men on their staffs to make a study of the questions involved, bringing to their aid the skill of the accountant, the engineer, the manager, the public officers entrusted with the affairs of these corporations, the business man, and the man who has devoted a lifetime, it may be, to a study of this class of problems. This work should not be done in a haphazard manner, but systematically and with one object in view, namely, to bring about as speedily as possible a clear understanding of all the facts on both sides. Such a work by our newspapers would not only add to the sum total of our happiness, but promote the prosperity and welfare of the communities which they serve. I sometimes wonder why the proprietors of newspapers do not see that their own business is in the nature of a public utility, morally at least.

It is perhaps unnecessary to refer in detail to all of the different items entering into the cost of the physical property of a public utility. Such items as the following are in general capable of being classified in an inventory, and are readily understood: Land for railroad rights-of-way, electric transmission lines, and pond flowage; land for the many kinds of buildings required, such as office and station buildings, round houses, car barns, power houses for steam and hydraulic plants; and land for reservoirs, dams, waterworks and gas plants. The buildings themselves, together with their furnishings and fixtures. The roadbed, rails, ties and bridges of a railroad; and the locomotive, passenger and freight equipment. The dam structure, water wheels, and generator of a hydroelectric plant. The boilers, engines and generators of a steam plant.. The tunnels and pipe lines of a heating plant. The pumping engines, water mains, hydrants and distribution system of a water works. The machinery, gas holders, and distribution system of a gas works. The conduits, manholes and distribution systems of electric lighting and power plants. The switchboard, machinery and apparatus of a telephone exchange; and the wires, pole lines, conduits and instruments of the distribution system. All of these items, and vastly many more, make up the physical structure of public utility plants. They are tangible, that is, they can be seen, counted, measured, weighed, and their costs determined. Materials and labor are the principal items in their creation and installation.

The plans and specifications of a utility plant having been completed, proposals for its construction are invited. The contractor figures the cost of every item as nearly as possible, adding various percentages to cover contingencies, that is, unforeseen difficulties of construction and oversights, some large and some small. He adds the costs of the necessary permits, the insurance required on the men employed and on the buildings during their construction; and finally he adds another percentage on the whole for his profits. The propriety of these percentages in figuring the cost of work in advance is so apparent as to cause wonderment that any question should ever have arisen as to the equal propriety of including them in making an appraisal of a property at any time after it was built. Happily this ignorance concerning many of the physical elements has been dispelled, and there no longer is any question of allowing the necessary percentages to cover contingencies, insurance, contractors' profits, engineering and superintendence.

In amount the contingency percentages, varying on the different things from 2 to 20 per cent and upwards, may be assumed to average not less than 10 per cent. One-half is usually applied directly to the items themselves, the other half as a percentage on the total cost of all the items. Insurance varies from 0.5 to 1 per cent. The contractor's profit should be estimated at not less than 10 per cent. Engineering and superintendence, like contingencies, varies with the different items from 2 to 10 per cent and over, an average being, say, 5 per cent. One-half is applied directly to the items themselves, the other half, as a percentage on the total cost of all the items, including contingencies and contractor's profits. If the insurance has not been included with the contractor's costs it should follow after engineering and superintendence, and may then be combined with taxes in a percentage varying from 0.5 to 1.5 per cent. In the application of these percentages, only the *general* engineering percentage should be applied to land, the cost of which embraces its own particular expenses of acquiring, including damages, deeds of transfer and the like.

In case the contract has been awarded to a general contractor, he may sub-let the different parts to other contractors, each of whom includes in his bid contingencies and other items proper for his particular part of the work and his profits. In such cases the cost of the plant includes, besides the contingencies and profits of the sub-contractor, similar items for the general contractor. A general contractor responsible to the owners for the success of all building operations would probably demand and receive not less than 10 per cent of the cost of the entire work covered by his contract; and instances are known where the general contractor's profit has been large,—20 per cent and more. The measure of his profit is usually determined by the nature of the work, that is, the difficulties and uncertainties involved. The building of the Detroit River tunnel is an example of where the general contractor made a large profit; but the uncertainties were such that it was not known in advance by anyone whether his profit would be large or small, or whether there would not be an actual loss.

Another method in vogue is to place all building operations in the hands of an engineering firm who makes all surveys, prepares the plans and specifications, and superintends the work from start to finish, making a charge therefor of 10 per cent on the actual cost of the work. This virtually amounts to a profit of 10 per cent, as the cost on which the percentage is based usually includes the salaries and wages of the men employed in the engineering work, and all traveling and office expenses as well. It is known as the "cost plus a percentage" plan. The engineering firm may be likened to the general contractor with this difference: The former takes his percentage on actual costs determined after the work is completed; and the latter, on the estimated costs made before the work is begun. Obviously the uncertainties involved would cause the general contractor to guard himself by making liberal estimates.

We come now to discuss certain other expenses chargeable to capital, but which are not so well understood. Taxes during the construction period is an item usually overlooked by the public. Obviously, any real estate acquired by a corporation for public utility purposes would be taxed the same as similar property owned by an individual. Taxes not infrequently are also imposed on structures built, even before any use is actually made of them. One very common error of the public is to assume that if municipally owned there would be no taxes on a public utility property. True, there would be no taxes levied directly against the property, but there would be the indirect taxes which every taxpayer would have to meet. To illustrate: A public service corporation has to pay certain taxes on its property, and they may be very large. If this property be acquired by the city, it bears no taxes. The same amount of money being required to meet the expenses of government, after as before, it follows that the citizens must make up the amount formerly paid by the corporation. If, however, the earnings remain the same, there will be money to pay the taxes out of earnings. But in that case presumably the rates or charges for service would remain the same, so that one of the alleged benefits of public ownership would disappear. The item of taxes is, in an appraisal, frequently combined with insurance, the amount of the item then varying from 0.5 to 1.5 per cent.

The item of organization, administration, and legal expenses usually follows insurance and taxes and precedes interest during construction. As used by some the term is rather elastic in being made to include all preliminary expenses, costs of promotion, certificates of necessity, mortgage tax, fees of incorporation, securing of franchises, and other general expenses. It is usually expressed as a percentage varying from 2.5 to 5 per cent, being applied to the sum of all preceding costs, including lands.

There arise in connection with many utility projects certain expenses which have come to be known as costs of promotion and promoter's profits. The terms themselves are rather infrequently used in appraisals, these expenses, if considered at all, being included under costs of administration. Administration is frequently combined with organization and legal expenses. Whatever may be said for and against costs of promotion and promoter's profits in the sense that they represent intangible elements in the nature of "rake-offs," there are, in a totally different sense, certain expenditures during both the construction period and the early operative period which are legitimate and necessary and best described as promotion costs. In the sense that a promoter forwards, advances and encourages, that is, contributes to the growth, enlargement and excellence of a utility project desired by the public, there can be no question that such costs are entitled to consideration in determining a reasonable charge for service.

As to a promoter's profit, its propriety may possibly be decided by considering to what extent one would be willing to contribute to a project, independent of its construction cost, to procure its establishment; or, were a utility now serving the public in some necessary capacity to be taken away, to what extent would you, as one served by it, be willing to contribute to it rather than lose it. Put it another way: A man says he can make a success of a utility the citizens want, or now have. You doubt its possibility but consent to a trial, and he does it. How much are you willing to compensate him for his energy and brains? This implies a conception free of bias, broad-gauged and just to all interests concerned, which can be had only by being fair and open-minded, and by carefully refraining from reaching any conclusion in advance. Obviously no percentage could be given for promoter's profits, but appraisals in which the costs of promotion have been ascertainable indicate that a proper charge may be as much as 2 per cent. Its allowance must depend on circumstances, and if included as a separate item, it must of course be excluded from administration costs.

Interest during the period of construction is an important item often overlooked in the past. This means simply that the money which has been expended from time to time during the progress of the work cannot be had without interest. If borrowed, it is secured by interest bearing notes; and if provided through the sale of bonds, these bonds bear interest. Ordinarily, the interest charge is based on the assumption that the money expended starts at zero, and mounts uniformly to the total at the end of the construction period. Thus the rate of interest is applied to one-half the total cost, or one-half the rate is applied to the total cost. The construction period varies with different kinds of property, one year, two years and three years being common lengths of time. It extends to the time when the property is put into operation and begins to earn. A rate of 6 per cent per annum is usually assumed.

The management of a public utility requires a home for its officers and the necessary furniture and fixtures. These may be rented, in which case the rent becomes an operating expense; or the company may own its offices and furniture and the special fixtures needed for its business. The cost then becomes a capital charge. In large properties, street and steam railways particularly, the offices, furniture and fixtures are frequently items of considerable expense. The cost of the equipment of offices, if incurred at the end of the construction period, does not involve interest during the construction period and the item can follow this interest. If, however, it has come earlier, its cost should enter into the sum on which interest during construction is computed.

Certain necessary stores and supplies must be provided ready for use in emergencies before the property can be put into operation. After the plant has been in operation for a time, these gradually adjust themselves as to quantities of the various items. The money represented by stores and supplies can bear no interest unless it be incorporated in the capital, or be carried as a floating debt. In either case the interest on this money becomes a proper charge against earnings. The amount considered is usually an average taken from the books.

Another item which occasions surprise is working capital. By this is meant the money which must always be available to pay bills, labor and the ordinary expenses of operation, and which in the very nature of the fund cannot bear interest except it be incorporated in capital, or be borne as a floating debt with interest paid out of earnings. In either case it becomes a charge against earnings, and therefore takes part as a factor in determining reasonable rates or charges. As between a capital charge and a floating debt it may be pointed out that as a capital charge the rate of interest would presumably be less than as a floating debt. A working capital is as necessary an expense as any other in the production of a public utility property. Without it the business for which the property was constructed could not be done. How often have we known of the failure of apparently good business enterprises merely for the lack of sufficient working capital? The amount of working capital, like stores and supplies, is usually an average taken from the books.

We have now reached the point at which the property has been completed, having considered items, all of which may enter into the capital investment, and are ready to take up the *second* principal factor, namely, operating expenses. With a working capital to hand, the property has been put into operation. · It begins to earn but a considerable time must elapse ordinarily before the earnings from operation suffice to meet all of the expenditures. By all of the expenditures I mean, interest on the cost of construction, taxes, operating expenses, a fund out of which the expenses of maintaining the integrity of the property can be borne, and another fund to provide for losses of capital at the end of the franchise period. These latter I will discuss separately under the head of "Depreciation" and "Sinking Fund," respectively. During this period of insufficient earnings, money must be borrowed to make up deficits; not only that, but interest must be paid on this borrowed money until the time that the earnings suffice to meet all expenses. This accumulated deficit constitutes what may be termed the cost of procuring a going concern; in other words, the cost of establishing the business. Were the property to change hands at the time the earnings just suffice to pay all expenses, the cost of establishing the business would become the going concern value of the property, and be a part of the total value of the property as a going concern *at that time*. It is a difficult element of cost to determine satisfactorily, in the absence of well kept accounts, starting with the property itself.

Not infrequently the point is made that the longer it takes to establish the business, that is, the greater the sum of its deficits in earlier years, the greater is its value as a going concern. This apparent inconsistency is explained by the fact that these deficits are real costs, and necessary if the utility is to be had at all. The utility being a necessity, it must be supported by the public the same as any other necessity. The cost of establishing the business therefore becomes a factor in determining reasonable rates or charges. This cost, like that of working capital, if incorporated in the interest bearing capital, becomes less of a burden against earnings than if carried as a floating debt.

Probably the least understood factor of expense in connection with a public utility property is depreciation. I have called this the *third* factor in determining a reasonable charge for public utility service. By depreciation, I mean the money required to be paid out of earnings in order to meet the expenses of maintaining the integrity of the property. Depreciation is the result of wear and tear and exposure to the elements. It also includes the replacement of machinery which, while not yet worn out, has become obsolete, that is, no longer economical to use; or if still economical, no longer satisfactory to the public. Depreciation includes, further, the wrecking of machinery due to accident, or to the acts of God.

In the building of a public utility property all of the elements are originally new, but as time goes on, these elements suffer wear or decay, some in one degree, some in another. When an element has become worn to a point where it is no longer profitable to keep it in service, it is replaced. Thus in time we have a property which as a whole is made up of old and new elements, the condition of which in the aggregate is something less than the first cost of these elements new. In the very nature of the property, it is impossible ever after it is once started to have present in it the full 100 per cent represented by all new elements. It can, however, be maintained in some condition less than 100 per cent, and it is usual and necessary to maintain it at a point which will enable the most satisfactory service to be rendered with the smallest expense consistent with satisfactory service. This point may be anywhere between 80 and 90 per cent, depending on the kind of property.

The expense necessary to keep an element in service during the useful life is a plain operating expense classed under maintenance and repairs, and is not included under depreciation as I am describing it. The depreciation fund is properly a separate fund, maintained as such as distinctly as an interest fund. It is the fund which insures the prolongation of the life of the property indefinitely and always in a condition to render satisfactory service. It is not, however, a fund out of which additions, extensions or betterments may be made, which in their nature constitute additions to capital.

Thus understood, depreciation becomes a factor, and indeed a very important factor in determining reasonable charges for public utility service. Unhappily, the practice of providing this fund is not uniform with the different utilities; not uniform either in principle or practice. It has long been common for some utilities, railroads for instance, to wear down in lean years and build up in fat years. Thus the condition of the property is not maintained in some uniform condition expressed as a definite percentage of the cost of all new elements, as for example, 80 per cent, but may vary all the way from 75 per cent to 85 per cent.

It is commonly believed by the public that a utility property should not be permitted to earn on more than the so-called present value of its physical elements, that is, their cost new, less depreciation, say 80 per cent of the cost new or less. As bearing on this, I have pointed out that the property, which by means of a proper depreciation fund can be maintained at some definite percentage which enables it to render satisfactory service, has cost 100 per cent. That is, the 80 per cent property cannot be had at all without expending the 100 per cent. Thus in order to have an 80 per cent physical condition, we must have a capital charge of 100 per cent. From this it becomes apparent that in determining a reasonable charge we must base it not on the percentage which represents condition, but on the cost of the property which cannot be maintained economically above an 80 per cent condition.

If, however, it be insisted that only that percentage of the total cost which is represented by the maintained condition of the property can bear an interest return, the loss of capital and interest thus incurred must be provided for out of earnings in another way, namely, by a sinking fund. This then is the *fourth* factor determining a reasonable charge for public utility service. It is to be borne in mind that in this entire discussion I am assuming only actual costs in the capital investment, and only such an interest rate as will induce the investment of the capital in the utility. At the end of the franchise period it is necessary to make good both principle and interest.

The importance of this sinking fund and its magnitude depend on the attitude of the public towards the utility company. The public service corporation works under a franchise, which is simply a grant by the public of the right to do business. With certain kinds of utilities the franchise is perpetual; with others, the life is limited to a definite period, say, 30 years. In some states, Wisconsin for instance, indeterminate franchises are granted; that is, franchises which can be called in, or surrendered at any time, subject to control by the Railroad Commission of that state. In the case of a limited franchise under which the utility company must cease operations and close up its business at the end of a definite period, the company must make not only enough to pay the interest on the cost of the plant and maintain it always in condition to render the service demanded by the public, as well as the operating expenses, including taxes, insurance and repairs, but also an additional amount to cover whatever part of the plant must be sacrificed at the end. This means a sinking fund to retire portions of the cost, if not the entire cost. In other words, the company must earn enough during its life to pay back whatever part of the principal has to be sacrificed, as well as the interest on the principal, in addition to maintaining and operating the plant satisfactorily during the franchise life.

This sinking fund is not always, indeed I may say, is not generally kept as a separate account in this country, but is taken out in the form of distributed earnings from year to year in excess of the amount normally required as interest on the cost. Not infrequently what appears as an abnormally large dividend will on analysis be found to be only sufficient in the end to make good to the investor both the interest on his money and the principal sacrificed when the business is closed out.

It should be clear from this that in general a long term franchise is more favorable to the public, so far as charges for service are concerned, than a short term. To illustrate: assume that the plant must be sold for what it will bring as scrap or second-hand material; the difference between its cost and sale value must be made up out of earnings during the life of the franchise. Thus, if the franchise life be short, say 25 years, the sinking fund annuity must be much larger than if the life be 50 years. No annuity is required, when the life is perpetual. No doubt longer term franchises will be granted in the future, particularly now that the control of them is being lodged by the states in public service commissions.

I am not discussing in this paper conditions which have existed in the past, or may exist now, in connection with old properties, but am confining myself to fundamental things, those which should guide us in our future relations; those relations which will come to exist when the public service corporation is permitted to earn only enough on its investment to bring capital into the field; that is, the critical condition, as it were.

There remains for me only one more topic, and this I have put off until the last, always shying at it and going around when possible. I refer to discounts on securities. This I have found: no bond house will even consider financing a public service corporation without a bond discount. I refer particularly to utilities built and operated under a limited franchise. It will have to be a good property to secure better than 15 per cent discount. It is an excellent property which commands as low as 10 per cent discount. The best discount I have ever come across in my own investigations is 8 per cent. This does not apply to municipalities, however, at least not to the same extent.

The simple conclusion is that if the public utility is a necessity and the money for it is obtained in the usual way, one element of cost is the discount on the bonds, which in effect starts the property off with some water in its securities. It is, or is not, water, as you view it. Anyhow it is necessary in the ordinary way of financing properties. Thus we are obliged, in determining a reasonable charge for public utility service, to consider not merely the actual cost as I have previously given it, but something more, namely, the face of the securities which command an interest return. Opinions differ on whether it is better for this discount to be absorbed as a capital charge or carried as an interest charge. So far as the purpose of this paper is concerned it is not material, as in either case there must be a charge against earnings to take care of the discount.

It will be convenient to bring together the several elements which take part in determining a reasonable charge for public utility service. Not all of them take part at the same time necessarily, for some may appear in one case and not in another; or several may be combined in a single item. In a general way, and in a somewhat natural order, they may be summarized as follows:

First, Capital Investment.

1. Preliminary costs covering investigations as to feasibility of project.

NOTE.—Organization, promotion, administration, and legal expenses, engineering and superintendence during construction, which are distributed over the whole period of construction, are more conveniently placed later in the schedule.

2. The physical property; the several items making up the whole arranged in order, each affected with its proper allowances to cover contingencies, special engineering, and other costs peculiar to the item; land first, followed by clearing and grub-

bing, then the various structures and equipment; sub-contractor's profits included with the separate items.

3. General contingencies applicable to the property as a whole as distinguished from special contingencies applicable to particular items.
4. General contractor's profits; or, the profits to an engineering firm building the property on the "cost plus a percentage" plan.
5. General engineering, and superintendence during construction.
6. Insurance and taxes.
7. Organization, administration and legal expenses.
8. Cost of promotion and promoter's profits.
9. Interest during the construction period.
10. Office furniture and fixtures.
11. Stores and supplies.
12. Working capital.

Second, Operating Expenses.

13. Operating expenses per se; that is, salaries, wages, fuel and other supplies, repairs and upkeep; all expenditures required in rendering the service of the utility, including insurance and taxes.
14. Interest on the capital investment (the actual cost of the property), i. e., interest on securities which must be paid regularly.
15. Interest on floating debts; this may include the discount on bonds, and the cost of financing, if these have not been incorporated with the capital.
16. Cost of establishing the business; the sums of money required to be borrowed, with interest on the same, to make good the differences between the earnings and expenditures up to the time the earnings become sufficient to meet all expenditures. This may be made a capital charge, or carried as a floating debt to be paid out of future earnings.

Third, Depreciation Fund.

17. The regular contribution to the depreciation fund, out of which the integrity of the property is to be maintained.

Fourth, Sinking Fund.

18. The annuity required to retire such portions of the securities as may be necessary at the expiration of the franchise life of the property, in order that the investor may receive back his entire principal when the business is closed out.

It will surprise everyone not familiar with the cost of building public utility plants to learn that the so-called overhead charges are in the aggregate a large percentage of the costs of labor and the material things entering into their construction.

An examination of the various percentages mentioned in discussing the elements of cost, omitting items 1, 4, 8, 15 and 16, will disclose that if the individual contingencies of construction, special engineering charges, and contractor's profits be assumed to be embraced in item 2, the total percentage may vary from 12 to 25 per cent; and if these inside percentages be added to the outside, or general, percentages, the total percentage may vary from 30 to 60 per cent.

It is to be regretted that engineers, and others who have had experience in building properties, and valuing them afterwards, have not done more towards disseminating knowledge of the actual conditions found in such work. We should then be much further along towards the mutual understanding which must exist before the public and the public service corporation can get together on common ground. But engineers have many times hesitated to use the larger percentages, fearing to be accused of favoring the corporation. They have preferred instead to secure the equivalent of them by using larger units of costs; or have used the smaller percentages, influenced by the feeling, unconsciously perhaps, that all things considered, the results were fair enough. In combining the judicial with their engineering function, they have unwittingly only obscured the issue. All too frequently engineers have felt obliged to exert themselves to the utmost in favor of their client, leaving the interests of the other side to be fought for with equal solicitude by an opposing engineer. Thus they have become advocates. This, in my opinion, is not the best way to handle these momentous problems. It would be far better in these troublesome times to throw open the blinds and let in all the light, our motto being *veritas vincit.*

TESTING OF HORIZONTAL LOWHEAD WATER TURBINES

At Elkhart, Indiana.

LUCIUS B. ANDRUS, MEM. A. I. E. E.

Presented November 24, 1913, at a Joint Meeting of the Electrical Section, W. S. E., and Chicago Section, A. I. E. E.

IN GENERAL.

The Elkhart hydro-electric plant, operated in connection with plants of the Indiana and Michigan Electric Company, is located on the south bank of the St. Joseph River in the northwest quarter of Section 4, Concord Township, Elkhart County, Indiana. The plant was built by the Elkhart Hydraulic Company—a company organized under an hydraulic act in the year 1865. The present hydraulic installation consists of two complete water turbine units for driving 2-1000 kv-a, 3 phase, 4 wire, 4000 volt, 60 cycle generator units and one water turbine unit for driving 1-100 kw., 125 volt, direct current exciter generator, with suitable oil pressure horizontal water wheel governors for controlling the speed of each water turbine unit. The general arrangement of these water turbines, generators, exciter, and governors is shown in Fig. 1.

The general arrangement of the testing equipment used is shown in Fig. 2.

WATER TURBINES.

Each generator water turbine unit consists of two pairs, arranged tandem, of 50-in. horizontal shaft, center discharge water turbines. Each of these turbine units, when operating under a net working head of 18 ft., is guaranteed to develop 1400 h. p. at full gate opening, using approximately 51,500 cu. ft. of water per minute when running at a speed of 120 r. p. m., developing horse powers under other various heads, as shown by the curves in Fig. 3, when running at 120 r. p. m., and guaranteed to develop these horse powers at efficiencies as shown by the curves in Fig. 4.

The exciter water turbine unit consists of one pair of 26-in. horizontal shaft, center discharge water turbines which, when operating under a net working head of 18 ft., will develop 170 h. p., using approximately 6250 cu. ft. of water per minute when running at a speed of 257 r. p. m.

LUBRICATION.

In connection with each of the aforementioned water turbine units is installed a complete system of positive lubrication, which will be briefly described for the reason that the friction losses of the turbines, and consequently the efficiency of the turbines, depends to some extent upon the effectiveness of the lubrication. The system of

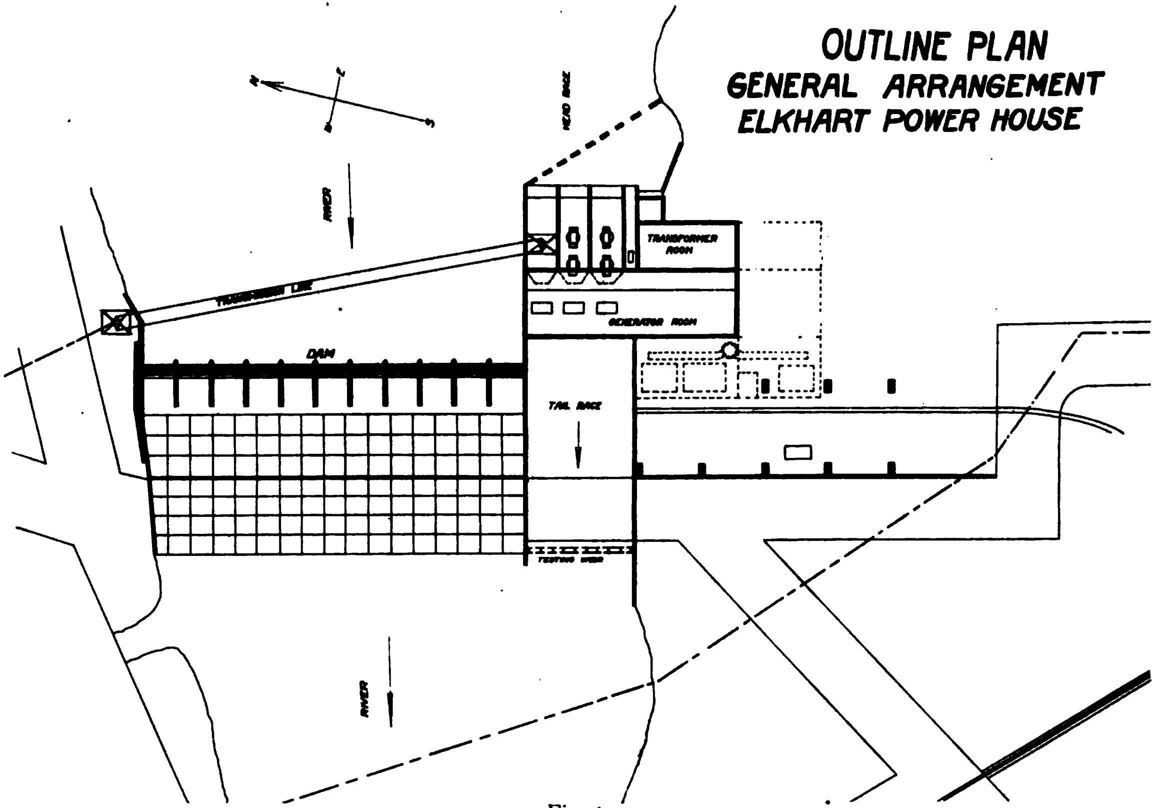
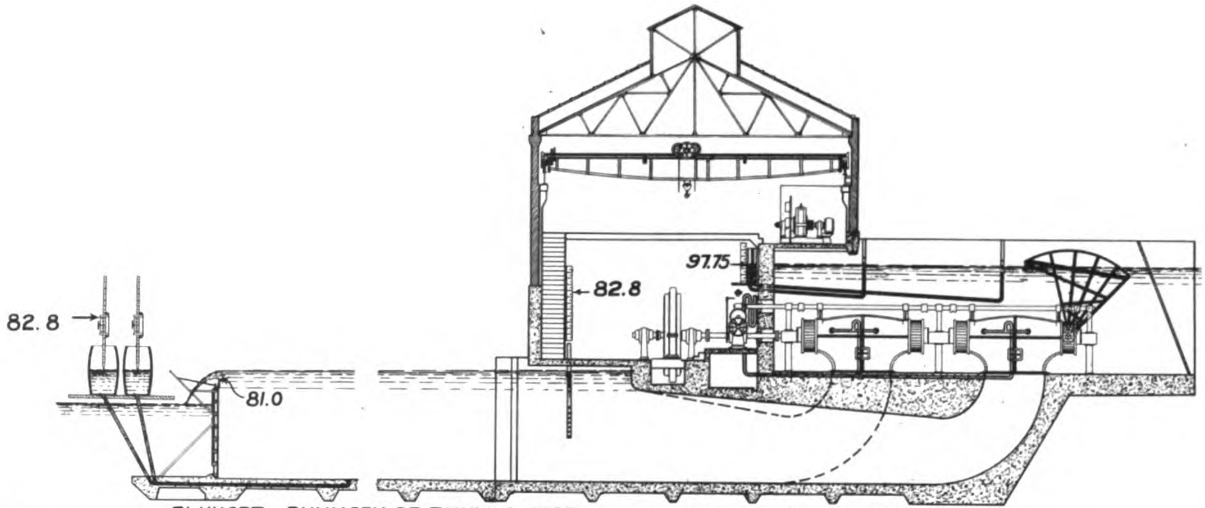

OUTLINE PLAN
GENERAL ARRANGEMENT
ELKHART POWER HOUSE
HEAD RACE
RIVER
TRANSFORMER ROOM
GENERATOR ROOM
TRANSMISSION LINE
DAM
TAIL RACE
TESTING WEIR
RIVER

Fig. 1.

ELKHART WATER WHEEL TEST

GENERAL ARRANGEMENT TESTING EQUIPMENT USED



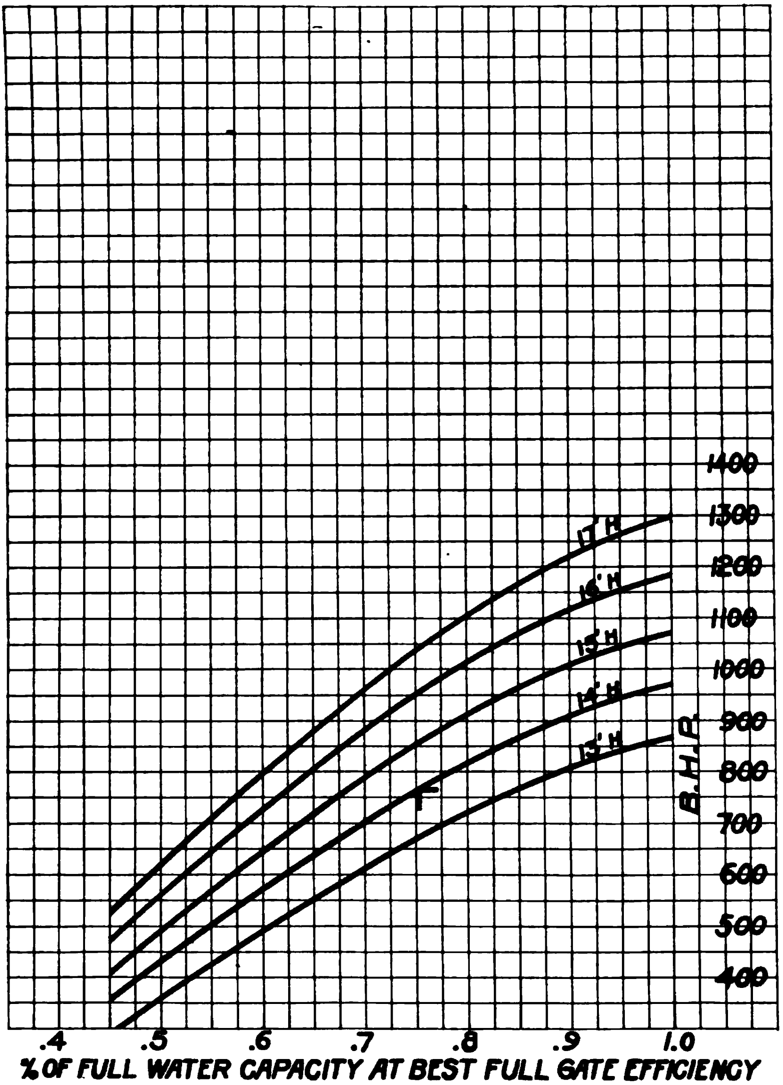
ELKHART—SUMMARY OF RUNNING TEST 4-50 INCH WATER TURBINES.

UNIT	RUN	TIME	SPEED	HEAD WATER ON WHEELS	TAIL WATER ON WHEELS	NET HEAD ON WHEELS	GATE OPENING	HEAD WATER ON BARREL CISTERN	ELEV. CREST OF WEIR	NET HEAD ON WEIR	DISCHARGE OVER WEIR	CORRECTED DISCHARGE OVER WEIR	K.W. LOAD	B.H.P.	EFF.
2	14	6:12 P.M.	120.0	97.75	82.8	13.95	.75	82.83	81.0	1.83	683	680	636 K.W. 3640 V. 96.4 Ef.	880	81.5

PLATE No 2

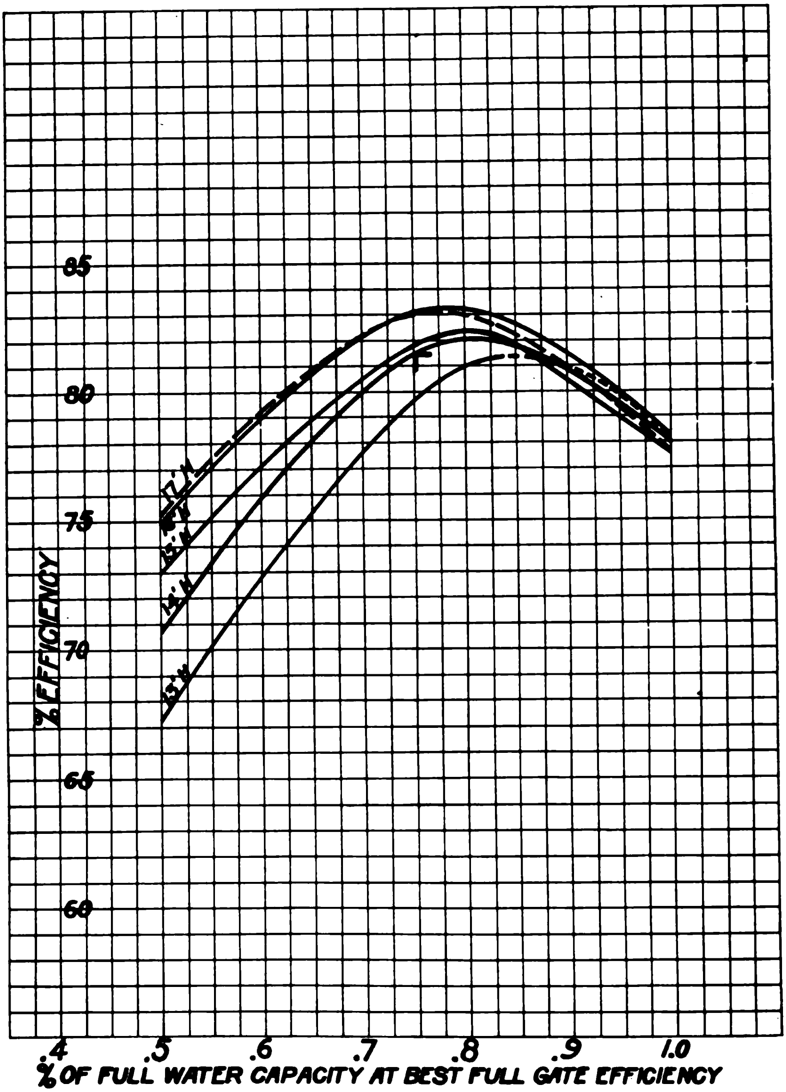
L. B. ANDRUS.

Fig. 2.



ELKHART WATER WHEEL TEST

Fig. 3



ELKHART WATER WHEEL TEST

Fig. 4

lubrication consists of a large grease compressor fitted with a suitable hand-wheel and gears for operating it. This grease compressor is piped to three cast-iron manifolds, to which are attached the various pipe connections between the valves on the manifolds and the shaft bearings of the water wheels which are normally operated under water. The manifold and valves are located inside of the power house, and from each of these valves a pipe is run to its respective bearing inside of the penstock. The design of the positive lubrication system is such that the grease pipes are laid on the penstock floor, and the risers to the bearings are rigidly attached in such a manner as to prevent any undue vibration in the grease pipes. Water-wheel bearings are lubricated by opening the valves on the manifold successively and after opening each valve, turning the hand-wheel on the grease compressor. This forces a given amount of grease from the compressor to the manifold and through the open valve and pipe connected to it into the bearing of the water wheel. After the said valve is closed the next valve is opened and the aforementioned method of procedure is followed out until all bearings have been lubricated.

GATE OPERATING CONNECTIONS.

The amount of water admitted to the water wheels is controlled by water-balanced gates, which gates are operated from a gate-operating ring, and the connection between the gates and the operating ring is made with short malleable iron links between the gates and the gate ring. The gates are opened and closed by revolving the gate ring, and in order to get a free and easy movement of the gate-operating mechanism, the gate-operating rings are automatically lubricated from the grease that is furnished to the water-wheel shaft bearing adjacent to the ring. The gate rings are operated with an operating device consisting of two connecting rods. One end of the connecting rods is attached to the gate-operating ring, and the other end is attached by means of a suitable connection to the gate shaft. The gate shaft is located on top of the turbine units, and the connecting rods are of such length that the weight of the gate ring is carried on the connecting rods, thereby making practically a floating ring. The parts of the gate-operating connections are so proportioned that the gate shaft turns about one-sixth of a full revolution, or through an angle of 60°, when making a complete gate movement from shut to open, or vice-versa. The gates are so designed that the balance of pressure is on the closing side, so that the gates will gradually close if any of the governor connections should break.

GOVERNOR CONNECTIONS.

With each of the turbine units is furnished all the necessary governor connections between the gate shaft and the water-wheel governors, including rocker arms and connecting rod. No gears are used for the governor connections, the governor being direct connected to the gate shaft in such a manner that through the means of the rocker arms and connecting rods, the gate shaft can be turned through an angle of 60° without the use of any intermediate gears.

WATER WHEEL GOVERNORS.

Each water turbine unit is equipped with a horizontal oil-pressure water-wheel governor of 30,000 ft.-lb. capacity. Each governor is furnished with an oil pump belt connected to the main generator shaft and also a pressure and vacuum tank. Each main unit governor is fitted with an electric speed control operated from the switchboard.

For controlling the speed of the exciter water turbine, a horizontal oil-pressure water-wheel governor of 2500 ft.-lb. capacity is used, and this governor is also furnished with an oil pump, belt connected to the exciter shaft and a pressure and vacuum tank.

GENERATORS.

Direct connected by means of suitable coupling on the end of each water-wheel shaft, is an electrical generator. The main unit generators are of 1000 kv-a capacity each, 4000 volts, 3 phase, 4 wire, 60 cycles, at 120 r. p. m., and the exciter generator unit is of 100 kw. capacity, 125 volts direct current, at 250 r. p. m.

WATER TURBINE TESTS AND GUARANTEES.

The water turbine manufacturer was required to state in his proposal, the efficiencies and horse power which the water turbines would develop under different operating heads and different gate openings, which were approximately as shown in Figs. 3 and 4. To make it possible to verify the specifications under which the water turbines were furnished, provision was made in the water turbine contract for a test of the water turbines relative to both the efficiencies and power outputs guaranteed by the water turbine manufacturers. The energy output of the water wheels was guaranteed at the generator end of the water-wheel shaft, and the water wheels were to be loaded to develop a certain horse power capacity by using the electric generators for this purpose. The brake horse power of the turbines was to be determined from the electrical output of the generators, as indicated by proper electrical instruments, and by dividing the electrical generator output by the respective efficiency of the electrical generator under the then condition of operation. The resulting figure would be a true measure of the energy output of the water wheels at the generator end of the water-wheel shaft.

In order to know just what the efficiency of the generator under the different operating conditions would be, the generators were tested in the shops of their manufacturer and a record of such tests was furnished for use in connection with the water-wheel test in the manner hereafter described. Such energy output measured in the aforementioned manner, reduced to brake horse power at the generator coupling, taken in connection with readings which would determine the speed and net head of water under which the water wheels were operating at the then condition of the test, will give a check on the power curves as guaranteed by the water turbine manufacturer.

In order to arrive at a figure representing the theoretical horse power in the water passing through the turbine at the then condition of test, the discharge water from the turbines was caused to pass over a testing weir constructed according to the Francis design. From the uniform depth of the water flowing over the testing weir and by use of the Francis formula, the cubic feet of water per second can be computed for each foot of length of the testing weir. This amount, multiplied by the total length of the testing weir over which said flow of water is taking place, will be, after correcting for the leakage through the weir and through the turbine gates, a true measure in cubic feet per second of the amount of water which passed through the runners of the water turbines under the then condition of test. The weight of this amount of water, when multiplied by the net working head of water on the wheels under the then condition of test and divided by 550, which is the foot-pound per second equivalent for one horse power, will give the theoretical horse power of the water which passed through the buckets of the turbine at the then condition of test.

The ratio of the brake horse power to the theoretical horse power will then be a true measure of the resulting efficiency of the water wheels under the then condition of test, and such efficiency, when taken in connection with the net operating head of the wheels and the speed under the then condition of test, will give a check on the efficiency curves as guaranteed by the water turbine manufacturer.

GENERATOR LOSSES.

Under the heading, "Water Turbine Tests and Guarantees," the following statement appears:

"In order to know just what the efficiency of the generator under the different operating conditions would be, the generators were tested in the shops of their manufacturer and a record of such tests was furnished for use in connection with the water-wheel test." The word *efficiency,* as defined in the standardization rules of the American Institute of Electrical Engineers, means, with reference to a piece of apparatus, the ratio of its power output to its power input, and, unless otherwise specified, the term is ordinarily assumed to refer to power efficiency. And this is the sense in which it is used in the aforementioned quotation. The power input to the generator is equal to the power output plus the losses in the generator. The losses which in the water-wheel test must be added to the generator power outputs, in order to give a true measure of the generator power input, are as follows:

(a) Core Losses.
(b) Bearing Friction and Windage Losses.
(c) Armature Resistance Losses.
(d) Load Losses.

The excitation losses were supplied from a motor-generator set operating from a separate system and had no influence with reference to the power output of the main unit turbine water wheel. The water-wheel governors were not used during the test and the governor pumps, which are ordinarily belt connected to the main water-wheel shaft, were not run. Consequently they had no influence with reference to the power output of the main unit turbine water wheel.

(*a*) *Core Losses.*

The core losses or iron losses in the generators are supplied mechanically and occur when the generator fields are excited from some external source. They manifest themselves in the form of a torque on the armature and, therefore, if the armature is driven at a constant speed by a motor, and the increased electrical input to the motor is noted as the excitation is increased, the increased power input to the motor is a measure of the power required to supply the core losses.

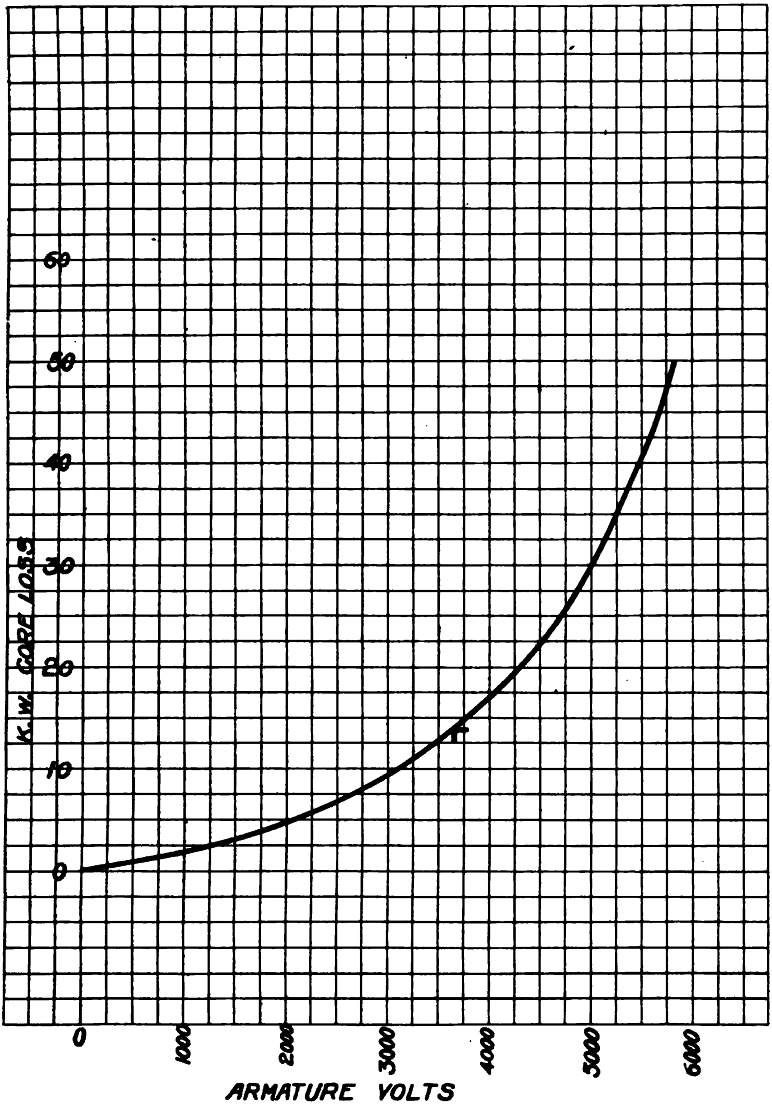
Assuming the motor to be driving the generator under test at its proper speed as a generator and with the field excited, as stated in the previous paragraph, with the power input to the motor noted, open the field circuit of the generator. This cuts off the external source of magnetization and the power input to the driving motor will be reduced by an amount equal to the iron loss of the generator under the then corresponding generator voltage. Now, if the new power input to the driving motor be subtracted from the power input to the driving motor before the field circuit is open, the difference may be taken as a correct measure of loss or iron loss of the generator. (Fig. 5.)

(*b*) *Bearing Friction and Windage Losses.*

It now remains to note the power input to the motor driving the generator at the correct speed without any field excitation. After so doing, take the driving belt off the motor and again start up the motor and find its power input without any load. This power input to the motor without any load, when subtracted from the power input to the motor when it was driving the generator without any field excitation, will give a difference which may be taken as a true measure of the losses due to bearing friction and windage. This loss will be constant at the constant speed at which the generators are run under test. (Fig. 7, col. 7.)

(*c*) *Armature Resistance Losses.*

The armature resistance losses are the losses which take place in the armature copper. This copper loss in any winding of a machine may be found by multiplying the resistance of the winding by



ELKHART WATER WHEEL TEST

Fig. 5

the square of the current flowing through the copper included in the resistance measurement. Using this method, it is sufficient to measure a resistance of the windings with the generators at rest. The resistance being measured from terminal to terminal of the armature, and on a 3 phase machine, such resistance may include two armature circuits or branches in series if the generator is **Y** connected, and may include the resistance of one circuit or branch in parallel with the other two circuits or branches if the armature is delta connected. This armature resistance loss may be calculated by multiplying the (resistance of one armature circuit or branch) by (the square of the current in such armature circuit or branch) by (the number of armature circuits or branches) (Fig. 6).

(*d*) *Load Losses.*

The load losses cannot be determined individually, but their joint influence can be determined by short-circuiting the generator and exciting the generator until full-load current is being circulated through the windings. By measuring the power necessary to drive the generator under these conditions, and subtracting the friction and windage loss and the calculated copper loss, the remainder will be the load loss due to eddy currents and losses in the iron parts. According to the American Institute of Electrical Engineers' standardization rule, one-third of said remainder can be taken as that load loss which would occur under actual load conditions.

GENERATOR EFFICIENCY.

By determining the aforementioned losses in the generator for various conditions of voltage and total load on the generators, and adding the sum of the losses at the then assumed conditions of voltage and amperage under which the losses were taken to the kilowatt output of the generator, which would be computed from the aforementioned voltage and amperage assumptions, at 100% power factor, the result of this addition would be a true measure of the power input to the generator when delivering such a load. The ratio of the aforementioned kilowatt power output to the kilowatt power input will be a true measure of the efficiency of the generator under the assumed conditions as defined above. By determining this efficiency at the various kilowatt loads, which will give the desired gate openings on the water wheels, and at the various voltages at which the desired loads can be secured, and plotting the same, we get a set of generator efficiency curves under the different conditions, as shown in Fig. 7.

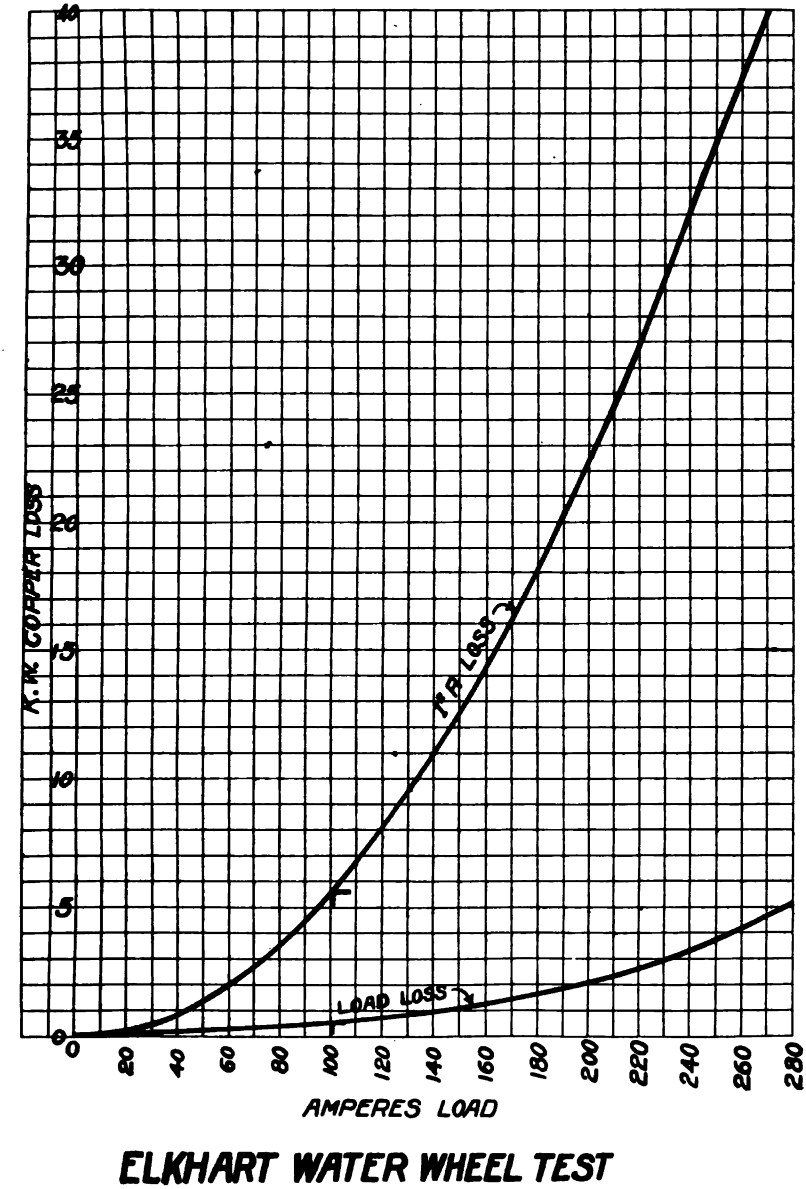

40
35
30
25
20
15
10
5
0
K.W. COPPER LOSS
I²R LOSS
LOAD LOSS
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
AMPERES LOAD
ELKHART WATER WHEEL TEST

Fig. 6

The tabulated computations from which the curves in Fig. 7 are plotted, are as follows:

GENERATOR EFFICIENCIES CALCULATED FROM FACTORY TEST SHEETS

Include: Core Loss, Friction and Windage, Armature Resistance Losses, and Load Losses.

Volts	Amps.	Output kw.	Core loss kw.	Arm. copper loss kw. at 25° C.	Load loss kw.	Friction and windage kw.	Total losses kw.	Input kw.	Eff.
3250	44.5	250	11	1.1	0.2	3.9	16.2	266.2	93.9
3250	89	500	11	4.5	0.5	3.9	19.9	519.9	96.2
3250	133.5	750	11	10.2	0.9	3.9	26	776	96.6
3250	178	1000	11	18	1.7	3.9	34.6	1034.6	96.7
3250	222.5	1250	11	28	2.6	3.9	45.5	1295.5	96.5
3250	267	1500	11	40.5	4.3	3.9	59.7	1559.7	96.2
3500	41.3	250	13	1.0	0.2	3.9	18	268	93.2
3500	82.5	500	13	3.8	0.5	3.9	21.2	521.2	95.9
3500	123.8	750	13	8.7	0.9	3.9	26.5	776.5	96.6
3500	165	1000	13	15.4	1.6	3.9	34	1034	96.7
3500	206	1250	13	24.1	2.2	3.9	43.2	1293.2	96.7
3500	248	1500	13	35	3.5	3.9	55.4	1555.4	96.4
3750	38.5	250	15	0.8	0.1	3.9	19.8	269.8	92.7
3750	77.0	500	15	3.4	0.3	3.9	22.6	522.6	95.7
3750	115.5	750	15	7.6	0.7	3.9	27.2	777.2	96.5
3750	154	1000	15	13.4	1.2	3.9	33.5	1033.5	96.8
3750	192	1250	15	21	2	3.9	41.9	1291.9	96.8
3750	231	1500	15	30.3	2.9	3.9	52.1	1552.1	96.6
4250	34	250	19.5	0.6	0.1	3.9	24.1	274.1	91.2
4250	68	500	19.5	2.6	0.3	3.9	26.3	526.3	95
4250	102	750	19.5	5.9	0.5	3.9	29.8	779.8	96.2
4250	136	1000	19.5	10.5	0.9	3.9	34.7	1034.7	96.6
4250	170	1250	19.5	16.4	1.5	3.9	41.3	1291.3	96.8
4250	204	1500	19.5	23.6	2.2	3.9	49.2	1549.2	96.8
4500	32	250	22.5	0.6	0.1	3.9	27.1	277.1	90.2
4500	64	500	22.5	2.3	0.2	3.9	28.9	528.9	94.5
4500	96	750	22.5	5.2	0.5	3.9	32.1	782.1	95.9
4500	128	1000	22.5	9.3	0.9	3.9	36.6	1036.6	96.5
4500	160	1250	22.5	14.5	1.3	3.9	42.2	1292.2	96.7
4500	192	1500	22.5	20.9	2	3.9	49.3	1549.3	96.8
4750	30.4	250	26.0	0.5	0.1	3.9	30.5	280.5	89.1
4750	60.8	500	26.0	2.1	0.2	3.9	32.2	532.2	93.9
4750	91.2	750	26.0	4.7	0.5	3.9	35.1	785.1	95.5
4750	121.6	1000	26.0	8.4	0.8	3.9	39.1	1039.1	96.2
4750	152	1250	26.0	13.1	1.2	3.9	44.2	1294.2	96.6
4750	182.4	1500	26.0	18.9	1.7	3.9	50.5	1550.5	96.7

GENERATOR EFFICIENCIES CALCULATED FROM FACTORY TEST SHEETS.

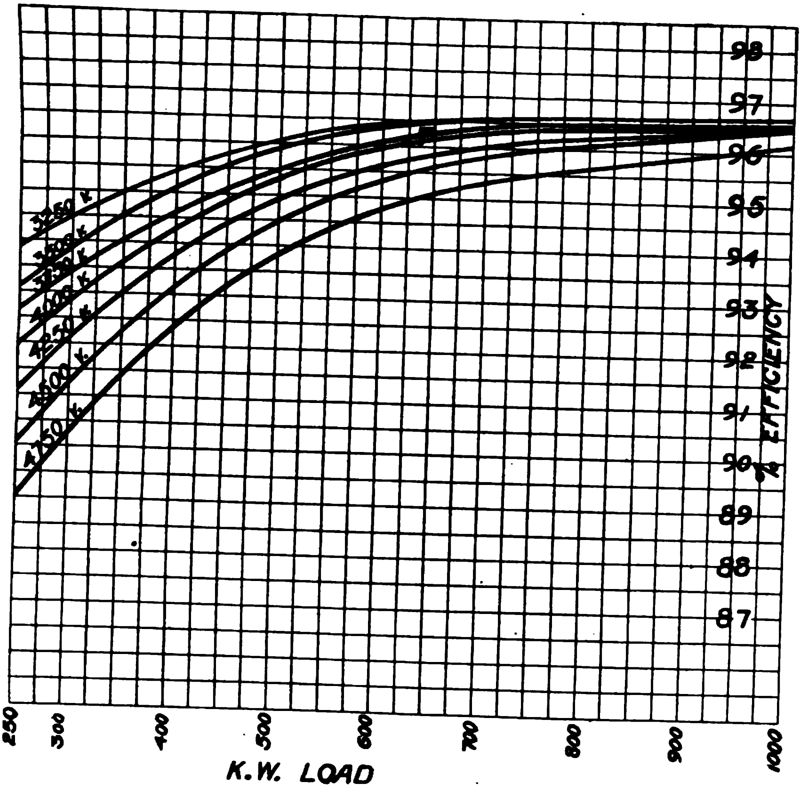
Include: Core Loss, Friction and Windage, Armature Resistance Losses, Load Losses (Armature Copper at 25 Deg. C.)

KILOWATTS OUTPUT.

Terminal Voltage Y	250	500	750	1000	1250	1500
3250	93.9	96.2	96.6	96.7	96.5	96.2
3500	93.2	95.9	96.6	96.7	96.7	96.4
3750	92.7	95.5	96.5	96.8	96.8	96.6
4000	92.0	95.4	96.4	96.7	96.8	96.8
4250	91.2	95.0	96.2	96.6	96.8	96.8
4500	90.2	94.5	95.9	96.5	96.7	96.8
4750	89.1	93.9	95.5	96.2	96.6	96.7

HOLYOKE TESTS TURBINE WATER WHEELS.

Leaving the subject of the Elkhart power house for a few moments, I desire to call your attention to a cross section of the Holyoke testing-flume as shown in Fig. 8.



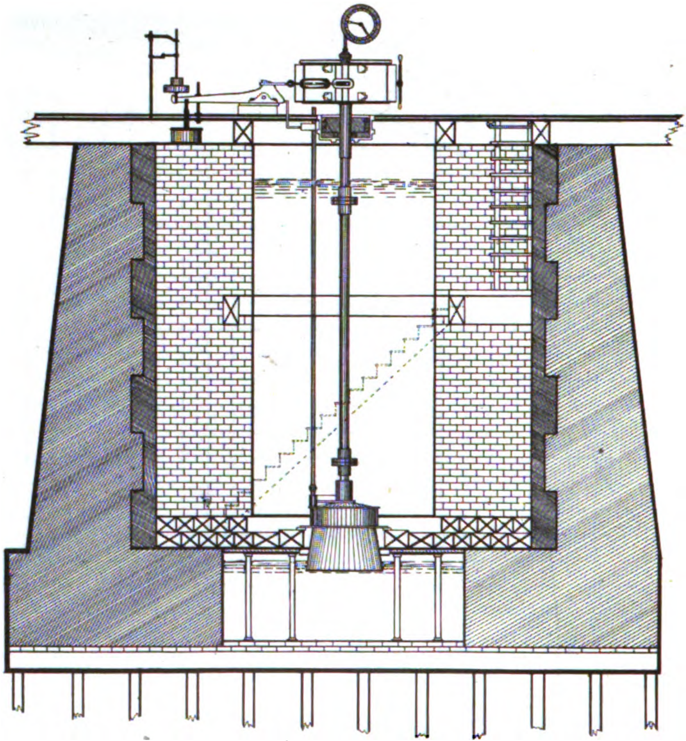
ELKHART WATER WHEEL TEST

GENERATOR EFFICIENCIES

VOLTS 1	AMPS. 2	OUTPUT K.W. 3	CORE LOSS K.W. 4	ARMATURE COPPER LOSS K.W. AT 25° C. 5	LOAD LOSS K.W. 6	FRICTION AND WINDAGE K.W. 7	TOTAL LOSSES K.W. 8	INPUT K.W. 9	% EFFICIENCY 10
3640	100	636	13.5	5.6	.6	3.9	23.6	659.6	96.4

Fig. 7.

This flume is owned by the Holyoke Water Power Company and is located at Holyoke, Massachusetts. The Holyoke Water Power Company controls the flow of the Connecticut River, at Holyoke, Mass., on a fall of nearly 60 ft. Above its dam is a drainage area of 8,144 square miles, as measured on the best maps in existence at the present time. At this date there are nearly 27,000 h. p. in use by day, and over 15,000 by night, of which part are "permanent powers," held by the parties using them under indentures, and sub-



HOLYOKE TESTING FLUME

PROPORTIONAL GATE OPENING	HEAD ON WHEELS	DEPTH ON WEIR	QUANTITY OF WATER PASSING THE WEIR C.F.P.S.	QUANTITY OF WATER PASSING THE WHEELS C.F.P.S.	WEIGHT ON DYNAMOMETER LEVER LBS.	REVOLUTIONS OF WHEELS PER MINUTE	H.P. DEVELOPED BY WHEEL UNDER ACTUAL HEAD	EFFICIENCY OF WHEEL %	RATIO OF DIS. OF WHEEL TO FULL GATE DIS. AT MAX. EFF.

Fig. 8

ject to annual rental; the balance are "surplus powers," held by the parties using them, subject to withdrawal at short notice. Surplus powers are paid for from day to day, and according to the amount used. In time of drought, if used after prohibition, the parties so using are liable to a heavy penalty.

There are at the present date 158 water wheels in use in Holyoke, of which 68 run about 10 hours per day, and 90 run from Sunday midnight to Saturday midnight, or 144 hours per week. The number of distinct establishments operated by these wheels is about 60. Observations are taken giving the opening of the speed-rate of each wheel and the head acting upon it, once a day, and once during each night. These are carefully preserved and from them are computed the amounts discharged by each wheel and by each establishment, during the quarter year, and the "surplus power" thus shown to have been used is paid for at the end of the quarter.

This system results in economy in the use of water, where otherwise there would be great wastefulness. In times of low water, it restricts the use of water, and, when need be, confines all parties to their indentured quantities. Before the introduction of this system of management, some parties would persist in using much more than their lawful quantity at any and all times, and in entire disregard of the rights of any other parties.

For the purpose of making the necessary experiments on the wheels of their tenants, before they are set in the mills, the Holyoke Water Power Company has built, at a large outlay, a permanent testing flume, shown in Fig. 8. Over this testing flume is a substantial brick building containing repair shops, blacksmith shop, and oil room and offices. Wheels are tested here both for power and for amount of water discharged. They are usually tested at five or six different openings of the speedgate, ranging from wide open, to the opening at which the discharge is one-half that at full opening, and at six or eight different velocities of revolution at each gate-opening, making some 30 or 40 experiments in all on each wheel. The final result is, that for all practical purposes the water wheel has been converted into a water meter, and its discharge may be known under any of the conditions under which it is found in the mill. Besides this, its efficiency, or the value of the wheel as a water-motor, is also known.

Being fitted to make these tests at any time, summer and winter, and with many tests to make, the expense of a single test, when made by the Holyoke Water Power Company, need be but moderate. In former years such tests could be made only in the mills where the wheel happened to be set, and at great expense for preparation, all of which preparation was available for that one wheel only. In this way the cost of a wheel test might readily amount to $2,500, where the Holyoke Water Power Company would now undertake to do it for $100.00 to $150.00. This has gradually led to the making of a great many wheel tests each year for outside parties who send wheels from all parts of the United States. As will be seen from the description of the testing flume, it is suitable, moreover, to the making of hydraulic experiments other than the efficiency test of wheels, and is used for such, from time to time.

As a result of the policy of the Holyoke Water Power Company making tests for water turbine manufacturing companies and supplying reports on such tests, more efficient use is now made of water, and the water-wheel manufacturers can, by having their wheels tested in the Holyoke flume, get such data as will allow of making fixed guarantees of the performance of their water turbines.

There are three factors of the Holyoke test which are practically fixed and do not apply to the conditions under which the water turbines will necessarily operate in a power installation.

(a) The head at Holyoke under which the wheels are tested may be considerably different from that at which the wheels will operate when permanently installed.

(b) The wheels are tested in a vertical position at Holyoke and may be erected in a horizontal position when permanently installed.

(c) The length of draft tube is fixed within limits in the Holyoke testing plant. The form of it is fixed, and the draft tube through which the wheels will discharge water when erected when permanently installed, may be of an entirely different length and shape, and in the final analysis it is the performance of the wheel when permanently installed that is of real value to the investors. The majority of water turbine manufacturers' guarantees are based on Holyoke tests, with a given allowance for the three aforementioned conditions which exist between the factors entering into the Holyoke test and the like governing factors under which the wheels will operate when permanently installed. And it was to the end that the accuracy of such allowances could be verified that the Elkhart water turbine test was provided for in the contract covering the water turbines, and was carried through, as hereinafter described.

With reference to the corrections for different heads as mentioned under (a), the heads can be checked very closely without the necessity of a complete test. However, with reference to the corrections as mentioned under (b), it was problematical as to the difference in performance of water turbines when set vertically and when set horizontally. With water wheels set vertically, the water necessarily leaves the wheel with some velocity, but the discharge from each different vane of the wheel does not necessarily interfere with the discharge from other vanes, and if there is such an interference, the effect is uniformly distributed around the wheel. With water wheels set horizontally, the water discharged from the top half of the wheel necessarily has to pass downward by the water discharged from the lower half of the wheel and may interfere with it and therefore subtract from the power and efficiency. At the same time, the water discharged from the bottom half of the wheel does not have to pass the water discharged from the top half. Therefore, if there is an interference, it will not be uniform about the wheel. This factor of discharging the water from the top half of the wheel without crowding it into the water discharged from the bottom half, can be taken care of largely by the shape followed in the design of the top half of the draft chest. However, assuming that the discharged water from the top half of the wheel was crowded down by the water discharged from the bottom half, there was a question as to how much this would detract from the power which the wheel could develop, as shown by the Holyoke test when in a vertical position, where such interference would not take place.

With reference to the corrections as mentioned under (c), which has to do with the length and shape of the draft tube, attention is again called to the fact that under the Holyoke test the length and shape were fixed within certain limits, while under the conditions under which the wheels will operate when permanently installed, the draft tube may be of an entirely different shape and length. The water turbine manufacturers make an allowance for the difference in draft tube conditions as used in the Holyoke test and as used when permanently installed. An approximation of the real difference resulting from the various shapes and lengths of draft tubes used in permanent installations can be arrived at only as a result of a test of the water wheels as permanently installed. A water turbine as permanently installed may be made to perform its work more efficiently than was shown by the Holyoke test, providing the draft tube conditions are better. An elementary conception of just how this can be true, may be reached from the following brief description:

The head or fall acting on a wheel is determined by physical conditions. It is the elevation of the upper pool or upper level, otherwise called the head water, above the lower pool or lower level, otherwise called the tail water. A wheel set any number of feet above the latter and discharging into the air loses so many feet of the head; but if it discharges through a vertical pipe whose discharge is below the lower level, the water will free the pipe from air, and the pressure against which the water issues from the buckets will be reduced by the exact equivalent of that part of the head between the center of the discharge-orifices and the tail water. In other words, the draft-tube renders the entire head available, though the wheel may set considerably above the lower level.

Theoretically, this height could not exceed that corresponding to the atmospheric pressure, otherwise there would be a vacuum immediately below the wheel and a part of the head would be lost. In practice, the draft head never reaches the limit and as a rule does not closely approach it. It is not, at first view, evident just why the air is expelled from the draft tube. When the wheels are not running and the draft tube is empty, the surface of the water in the draft tube stands at the same level as the surface of the water in which the discharge of the draft tube is submerged which, in our case, would be the level of the tail water. When the water turbine gates are opened and the water passes through the wheels, the water fills the inside of the draft chest in a more or less solid condition and becomes mechanically mixed with the air. As a result, when the water discharges through the draft tube, the air is carried out with the discharge water in the form of air bubbles, for the reason that the velocity of the water through the draft tube is faster than the velocity at which the bubbles of air would rise in the water and free themselves. By giving a flare to the draft tube, that is, increasing its area as it leaves the draft chest in which the wheels are encased, it is possible to employ the momentum with which the water leaves the wheel, in diminishing the back pressure or pressure acting against the discharge of the wheel. Its practical effect is to slowly increase the head acting on the wheel. The extent to which it increases the head acting on the wheel is represented by the difference between the head due to the velocity with which the water leaves the wheel, and the head due to the velocity with which the water leaves the enlarged section of the draft tube. This is shown in the following example:

51,000=cu. ft. per min. two pair
=850 cu. ft. per sec. two pair
=425 " " " " one pair

Area at entrance of draft tube elbow 70 sq. ft.

$$\frac{425}{70} = 6 \text{ ft. per sec. velocity at entrance of draft tube elbow.}$$

$$H = \frac{V^2}{2g}$$

$$= \frac{36}{64.4}.$$

=0.56 equivalent head for velocity.

Area at discharge of draft tube elbow 90 sq. ft.

$$\frac{425}{90} = 4.6 \text{ ft. per sec. velocity at discharge of draft tube elbow.}$$

$$H = \frac{21}{64.4}$$

=0.325 equivalent head for velocity.

Gain in head from draft tube

$$0.56\text{ ft.} - 0.325\text{ ft.} = 0.235\text{ ft.}$$

Percent gain in 18 ft. operating head

$$\frac{0.235}{18\text{ ft.} - 0.56} = 1.62\%$$

The effect of the 1.62% additional head, by increasing the velocity of the water which passes through the wheel, will therefore increase the quantity of water discharged by the wheel for the same gate openings. Therefore, the effect of 1.62% increase in head due to the design of the draft tube, will increase the power of the wheel, which power varies as the product of the net working head on the wheel into the quantity of water discharged by the wheel and is therefore doubly beneficial. The aforementioned elementary example has been chosen for the purpose of illustration, and is meant to show that the difference in draft tube conditions, as existing under a test in the Holyoke testing flume and as existing where the wheels are permanently installed, may materially affect the power and efficiency of the water wheels.

TEST WEIR.

The test weir over which all the discharge water from the water turbines was made to pass, was located 172 ft. downstream from the discharge end of the water turbine draft tubes. This test weir was built across the tail race between the two concrete side walls of the tail race. (Figs. 1 and 2.) The tail race across which the test weir was built is of rectangular cross-section with vertical concrete sides and concrete bottom. The tail race is designed to discharge water from three main units and one exciter unit. Therefore, during the test when one main unit only was in operation, the discharge velocity was very low, and by placing the test weir 172 ft. downstream from the discharge end of the draft tubes, it had the effect of giving a weir discharge from the relatively quiet pond. The test weir was designed with a thin edge and the following requirements have been found desirable, in order to assure the accuracy of weir gagings:

(a) The upstream crest edge of the weir should be sharp and smooth.

(b) The upstream crest edge should be level from end to end.

(c) The overflowing sheet of water should touch only the upstream crest edge.

(d) The nappe should be perfectly aerated in such a manner that a vacuum will not be formed under the sheet of water and distort the shape of the discharge crest.

(e) The upstream face of the weir should be vertical.

(f) The measurements of the head of the water over the weir should show the true elevation of water surface a sufficient distance upstream from the crest edge of the weir to be unaffected by the surface curvature caused by the discharge over the weir.

WEIR HEAD WATER GAGINGS.

By reference to Fig. 2, it will be seen that the method of getting the elevation of the water surface above the level of the weir crest is accomplished by using equalizing pipes laid in the floor of the tail race, the entrance to which pipes is 30 ft. upstream from the crest of the test weir and the discharge end of which pipes leads into a barrel cistern. These pipes act as equalizing pipes and the height of the water in the barrel-cisterns will be the same as the height of the water in the tail race 30 ft. above the crest of the weir, which satisfies condition (f); that is, this elevation is taken far enough upstream from the crest of the weir to be unaffected by the surface curvature caused by the discharge over the weir. The head in the barrel cisterns is measured directly by graduated hook gages, which gages are set before the test and which refer back to the bench mark datum plane, to which all readings of elevations taken during the test are referred.

With reference to condition (d), which states that "the nappe should be perfectly aerated," this is accomplished by placing planks so as to break up the surface of the discharge water after it has passed over the weir, at such intervals as will admit sufficient air under the sheet of discharge water, to prevent a vacuum being formed under the sheet of discharge water and distorting its shape. In order to insure that the aeraters do this, a pipe can be temporarily placed in a vertical position so that the lower end projects through to the under side of the sheet of discharge water over the weir, and the top end of the pipe to be above the sheet of discharge water over the weir. Now, if there is a vacuum created underneath the sheet of discharge water, there will be a suction of air downward through this pipe, which suction will distort a match flame held over the top opening of the pipe.

The other conditions, a, f, c and e, and the precautions to be taken to secure accuracy of weir gagings, have been fulfilled, as can be seen by referring to the general construction of the test weir as shown in Fig. 2. In order to get the average level of the water across the entire tail race, there are four equalizing pipes placed in position, the entrance to which is distributed across the tail race, and there were four barrel cisterns used, only two of which are shown in Fig. 2 for illustrative purposes. The average of the elevation of the water in the four barrel cisterns can be taken as the true average elevation of the water upstream from the crest of the test weir.

WEIR DISCHARGE CORRECTIONS.

(*a*) *Correction for Velocity of Approach.*

Under the hypothesis of this discussion of test weir, the water is assumed to be discharging downstream. Therefore, the head as measured in the barrel cisterns will be measured at a point where there is some velocity due to the discharge water from water-wheel turbines flowing downstream and over the test weir. It has been found by various experimenters with weir formulae, that a current velocity of 1 ft. per second would introduce an error that would amount to about 2% when there was approximately 12 in. of water flowing over the crest of the test weir; that is, the discharge would be about 2% greater than if computed by the generally accepted Francis formula

$$Q=3.33\ LH^{3/2}$$

Therefore, it is necessary to make a correction in the generally-accepted Francis formula. The discharge curve as shown in Fig. 9, is plotted from computations for the discharge over the Elkhart test weir and is corrected for velocity of approach.

(*b*) *Correction for Weir Leakage.*

The correction for weir leakage is made as follows:

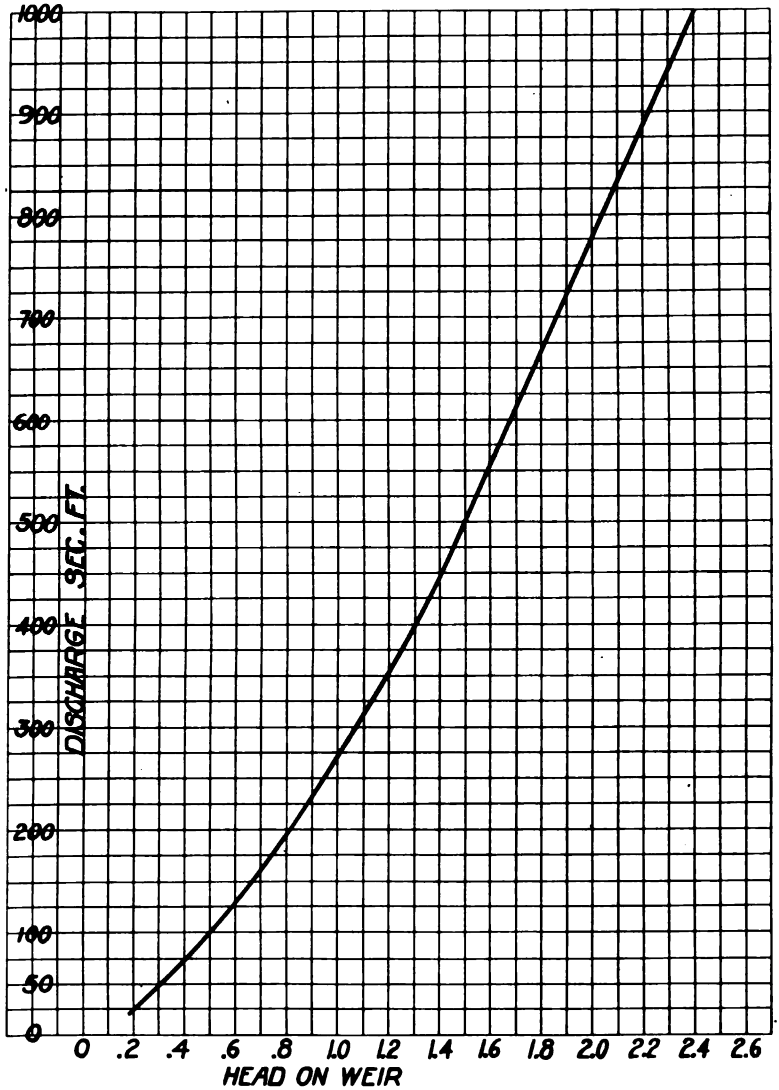
The tail race above the test weir is filled with water until there is a sheet of water discharging over the crest of the test weir. All gates and valves, including drain valves and turbine penstock head gates, are then closed and made water tight and the water is allowed to discharge over the crest weir until the level of the tail race pond is the same as the level of the crest of the test weir, at which time the water will stop flowing over the crest of the test weir. By observing the drop of the level of the tail race pond below the crest of the test weir over a given period of time, and by knowing the cubic feet of water which must have leaked through the test weir in order to cause this drop, over said period of time, the correction for leakage through the weir can be computed. In the Elkhart test there were two main units to be tested; therefore, when running one unit under test, one-half of the leakage should be added to the quantity of water which is being discharged over test weir at the then condition of test.

(*c*) *Correction for Turbine Gate Leakage.*

The correction for turbine gate leakage is computed as follows:

The turbine water wheel gates are placed in the full closed position; the turbine penstock head gates are then opened and after a suitable length of time the amount of water flowing over the crest of the test weir will be a measure of the leakage through the water turbine gates. This water is assumed to pass through the turbines without doing any useful work and if the test is made as at Elkhart, with both turbine penstock head gates open, afterward, when testing one unit, one-half of the leakage should be subtracted from the quantity of water which is being discharged over the test weir at the then condition of test.

The correction for velocity of approach has been taken into consideration in plotting the curve as shown in Fig. 9.



ELKHART WATER WHEEL TEST

Fig. 9

WATER WHEEL EFFICIENCIES.

After ascertaining from the readings at the then condition of test the head of water flowing over the crest of the test weir, and by use of the curve shown in Fig. 9, we arrived at the total cubic feet of water per second being discharged over the crest of the test weir. Then adding the correction for leakage through the test weir, as described under paragraph (b), and subtracting the correction for leakage through the turbine gates, as described in paragraph (c), the remainder will be the true cubic feet of water per second which was doing useful work in the water turbines at the then condition of test. This quantity of cubic feet of water per second, multiplied by its weight and by the net working head as shown on the wheels (see subsequent paragraph, "Net Head of Water on Water Turbines") at the then condition of test, and this product divided by 550, gives the theoretical horse power in the water. (Fig. 10.) The theoretical horse power when divided into the mechanical input to the electrical generators will give, as a resulting quotient, the efficiency of the water wheels under the then condition of test, and such efficiency will give a check on the efficiencies as guaranteed by the water turbine manufacturers.

HEAD WATER READINGS ON WATER TURBINES.

The head water readings on the water turbines were taken from the elevation of water standing in large glass tubes in the power house, as shown in Fig. 2. There were two glass tubes for each turbine penstock. In the side wall of each penstock is placed a vertical 4-in. pipe extending below the water level with ½-in. pipes, one above the other at different elevations extending to and ending flush with the inside face of the penstock walls. By this arrangement the ½-in. pipes between the penstock walls and the vertical 4-in. pipe were at approximately right angles to the direction of flow of the water and were, therefore, not influenced by the water currents in the penstock. Equalizing pipes connected the 4-in. vertical pipes in the penstock walls to the aforementioned glass tubes in the power house. Therefore, the water in the 4-in. vertical pipes stood at the same elevation as the water in the penstock, and the water in the glass tube stood at the same elevation as the water in the vertical 4-in. pipe, and as before mentioned, there were two vertical 4-in. pipes, one in each side wall of each penstock; then the average of the readings of the elevation of the water in the two glass tubes at the then condition of test was taken as a true measure of the elevation of the head water under which the water turbines were operating.

TAIL WATER READINGS ON WATER TURBINES.

The tail-water readings on the water turbines were taken from the elevation of water standing in vertical 4-in. pipes extending below the water level in the side walls of the discharge end of the water turbine draft tubes. The 4-in. pipes were so placed as to come

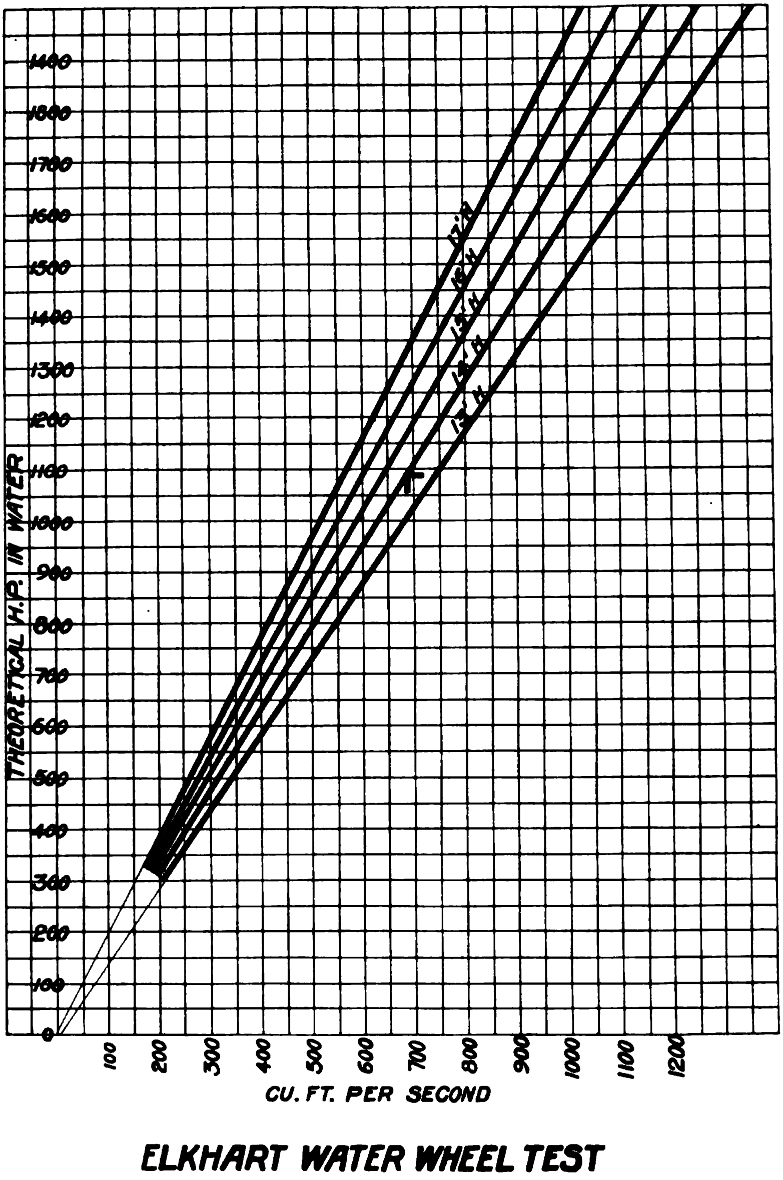
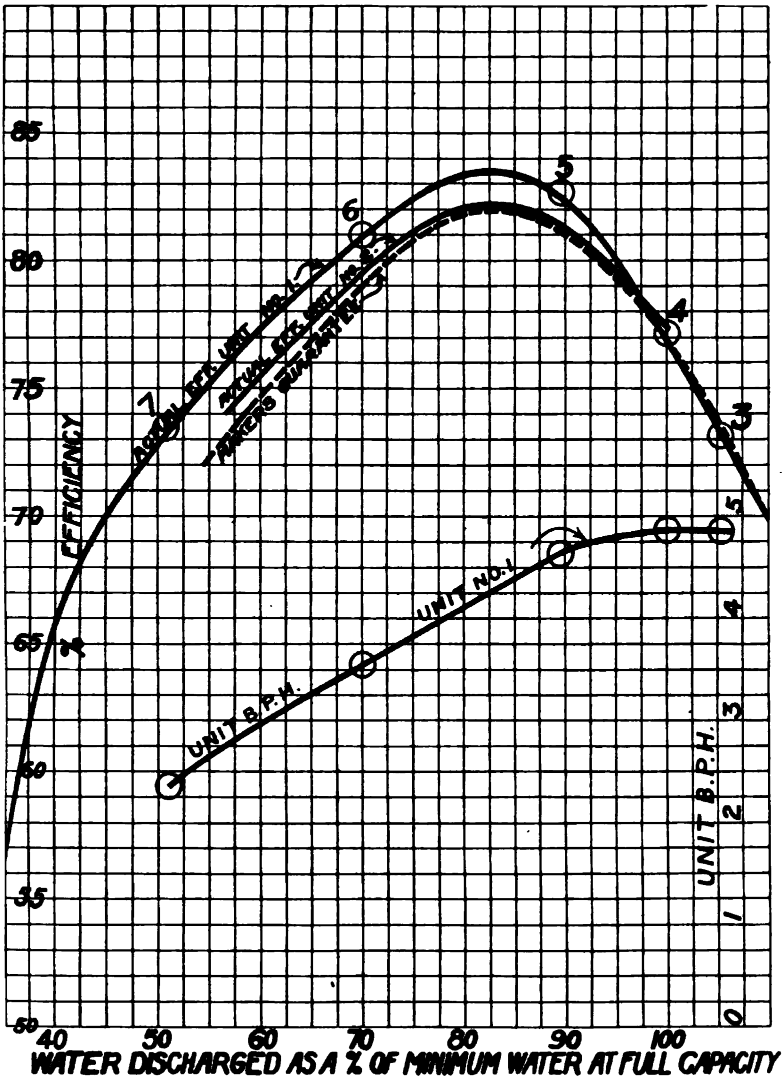
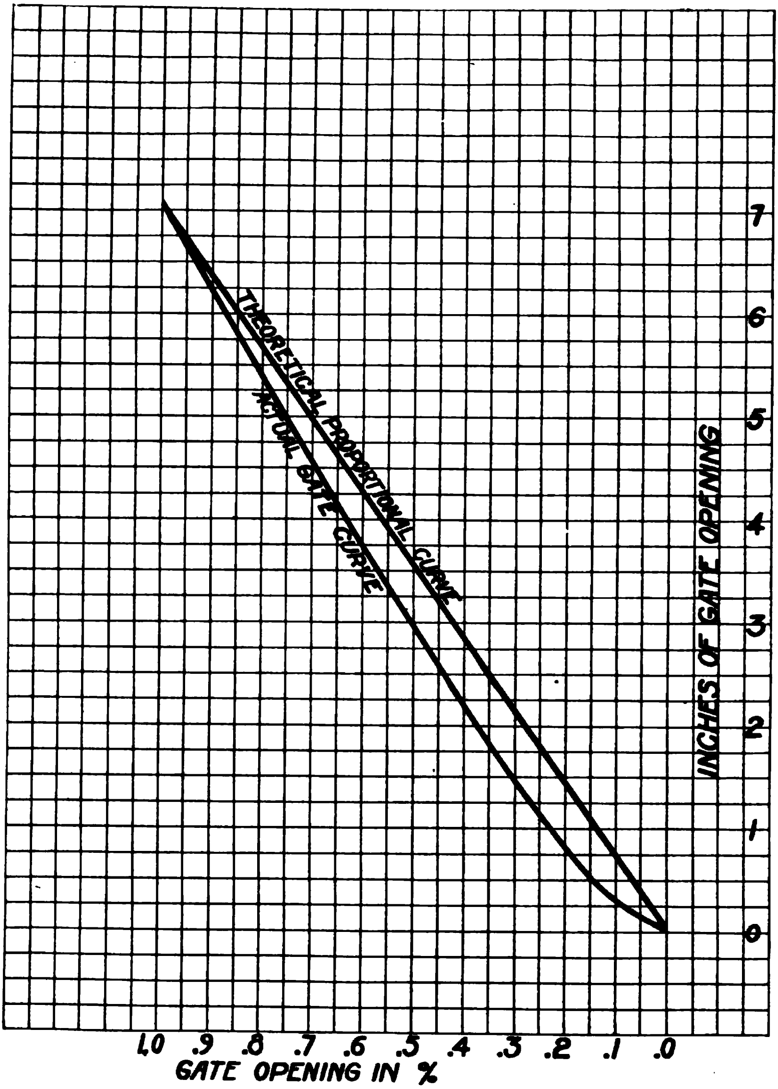

THEORETICAL H.P. IN WATER
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
17 H
16 H
15 H
14 H
13 H
100
200
300
400
500
600
700
800
900
1000
1100
1200
CU. FT. PER SECOND
ELKHART WATER WHEEL TEST

Fig. 10



EFFICIENCY CURVE
ELKHART WATER WHEEL TEST

Fig. 11.



GATE OPENING

ELKHART WATER WHEEL TEST

Fig. 12.

flush with the inside face of the wall on the discharge end of the water turbine draft tubes. Holes were drilled one above the other at different elevations along the line at which the 4-in. pipe was tangent to the inside face of the wall of the water turbine draft tubes, and this made the holes at right angles to the direction of flow of the water in the draft tubes. Therefore, the water standing in the vertical 4-in. pipes was not influenced by the water currents in the draft tubes. These 4-in. vertical pipes extend through and up into the power house to such a height that the highest elevation of tail water maintained during test would not overflow the pipes and flood the power house floor. The tail-water gages were placed immediately over these 4-in. pipes and the gages proper were operated by floats in the 4-in. pipes; the reading of the tail-water gage at the then condition of test was taken as a true measure of the elevation of the tail water.

NET HEAD OF WATER ON WATER TURBINES.

The difference between the head-water readings and the tail-water readings, as observed under the conditions described in the two previous paragraphs, was taken as a true measure of the net head of water under which the water turbines were operating at the then condition of test.

POWER DEVELOPED BY HORSE POWER.

The brake horse power of the turbines was to be determined from the electrical output of the generators, as indicated by proper electrical instruments, by dividing such electrical output by the respective efficiency of the electrical generator under the then condition of operation. The resulting figure would be a true measure of the energy output of the water wheels at the generator end of the water wheel shaft. Such reading expressed in horse power, and taken in connection with readings which would determine the speed and the net head of water on water turbines, taken in accordance with the paragraph, "Head Water Readings on Water Turbines," would give a check on the power curves as guaranteed by the water turbine manufacturer.

PURPOSE OF TEST.

The purpose of the test, as described in previous paragraphs of this paper, was to check the water turbine manufacturer's tables of efficiencies and brake horse power developed under various conditions of operating net head of water on water turbine. Such guarantees are shown plotted graphically in Figs. 3 and 4; the water wheel efficiencies computed as described in paragraph, "Weir Discharge Corrections," and the brake horse power developed by the water turbines computed as described in paragraph, "Tail Water Readings on Water Turbines," furnishes the desired check on the efficiencies and power developed by the water turbines and can be used to verify those guaranteed by the water turbine manufacturer.

METHOD OF CONDUCTING THE TEST.

The electrical method of determining the power output and efficiencies of the water turbine, as described in the previous paragraphs, was used. The brake horse power of the turbines was determined from the output of the generators, divided by the respective efficiency of the generator under the then condition of test. The theoretical horse power of the turbines was determined by knowing the operating head and the amount of water which passed through the buckets of the turbines as determined by the use of the testing weir. The ratio of the brake horse power to the theoretical horse power was taken as a measure of the resulting efficiency. A water rheostat was used as a means of furnishing the desired load for the electrical generator.

A test on a unit consisted of several runs, each covering a period of at least 15 minutes in order to insure stable conditions, and during such run readings were taken at intervals of one minute. A different condition of load was established for each run and as a result of such change in load, each different run constituted a test on the water turbines at a different load and using a different quantity of water.

DETERMINATION OF MAXIMUM DISCHARGE AT MAXIMUM EFFICIENCY.

The first condition to establish is that of the maximum discharge from the turbines at maximum efficiency. This point can be determined by starting in with a full-gate opening on the water turbine and adjusting the electrical load to bring the water turbine to the speed under which the guarantees are to be verified. By gradually closing the water turbine gates and carefully observing the electrical instruments used to measure the generator output, the point can be determined at which the electrical output commences to decrease as the water turbine gates are closed. The gate opening at the then condition of operation immediately preceding the decrease in electrical load, is the gate opening at which the maximum efficiency at maximum discharge is realized. The flow is then determined by means of the test weir for this condition of maximum discharge for maximum efficiency, and during the remainder of the test at partial loads the discharge as measured is computed in percent of this maximum discharge for maximum efficiency. This is referred to in Fig. 4 as "% of full water capacity at best full gate efficiency." To summarize, we can say that if, after placing the water turbine gates at 0.9 open, the generator will pull just as much load as when the water turbine gates are full open, the 0.9 gate opening represents a point of maximum discharge at maximum efficiency. In other words, the additional discharge of water secured by opening the gates from 0.9 open to full open did not do any additional work, and consequently the efficiency commences to fall off above 0.9 gate opening. The realization of this point of maximum discharge at maximum efficiency lies in the design of the water turbine.

OBSERVERS.

About 25 observers were used in taking readings at the different stations where gages were located. Each observer was furnished with a field book with loose leaves inserted, numbered consecutively and rolled up in a manner to give a consistent form of record. Instructions such as the following were issued to each observer:

(a) Do not exchange books.
(b) Do not destroy any sheet or any part of any record.
(c) Make no erasures. Pencil out and re-write.
(d) Sign all records.

(e) Check, before and after test, your watch against the watch used as a standard, and record the indicated time of both watches on your test sheet at the time of the checking.

(f) Note any contingencies which may arise during test, such as disturbances in water or on instruments, etc.

SYSTEM OF TAKING READINGS.

In order to insure simultaneous readings at the then condition of test, a bell circuit was run to the different test stations and electric bells installed within plain hearing of the observers, which bells were operated from a master push button in charge of a time observer assigned to this station.

The bell signals used were as follows:

(a) One long ring—observers leave for their places; see that everything is in working order. Read and record instruments and watches.

(b) Six short strikes—final warning that the run is to begin at once.

(c) Two strokes—make ready to read instruments.

(d) One stroke—Read instruments and record reading and the time to the nearest minute.

(e) After 50 seconds, two strokes again, same as before.

(f) After 10 seconds, one stroke, same as before.

(g) Thereafter every 60 seconds two strokes are sounded as warnings to be ready to read when one stroke is sounded.

(h) Draw a line under your last reading when one "jig" is sounded. "Jig"————————————

(i) Draw two lines under your last readings, when two jigs are sounded.

(j) At your earliest convenience average the readings between one jig and the following two jigs and record total and average in small figures at the side of these observations.

(k) Two long bells. The run is over, but do not leave your station.

(l) Three long bells—leave your station and come in.

(m) Four long bells—bring in your instruments, tapes, lanterns, stoves, etc., as entire test is finished.

RUNNING CHECK.

For the information of the engineer in charge of tests and such other representatives of interested parties as were permitted to keep a running check as the tests progressed, the following method was used:

Each uninterrupted run extended over the period of approximately 15 minutes, with readings taken at one-minute intervals. Under conditions of test as existed at Elkhart, the 5-minute interval was sufficient to insure a stable condition at all observation stations. The remaining ten readings, taken at one-minute intervals, could therefore be used in making a running check of the test.

During each uninterrupted run a messenger was sent from the desk of the engineer in charge of tests to each observation station, and the men were advised of the number assigned to that particular run; this number was then entered on their records in order to identify the readings taken during such run.

When a running check was desired, and as soon as stable conditions of test were established, one jig on the signal bells, as outlined above, was sounded, and after the desired number of readings taken at one-minute intervals had been made, two jigs on the signal bells, as outlined, were sounded, and at the earliest opportunity afterward the observers averaged the readings between the one jig and the following two jigs and recorded this average in small figures at the side of the observed readings included in the computed average.

Immediately thereafter the messenger or messengers would bring in such averages from the observation station to the engineer in charge of test. He would then take such readings, and, by use of such graphical charts as are shown in connection with this paper, get the equivalents in the desired units and enter them, as is shown under the head of "Summary of Running Test," Fig. 2.

By following the procedure as outlined, the engineer in charge and other interested parties were enabled to know, within a very close percentage of accuracy, just what was being realized, in the matter of power and efficiency, from the water turbines under test, and such a check would be available within 5 or 10 minutes after the run was completed.

DISCUSSION.

D. W. Roper, M. W. S. E. (Chairman): It has been stated that the development of electrical engineering has contributed to the advancement of other branches of engineering by offering to all engineers methods of measurement more refined than the ones to which they had been accustomed. This is particularly the case in connection with prime movers of various kinds, where it is very easy to measure the output in an accurate manner if the output is electrical, but more difficult, in fact, impossible, to measure with the same accuracy if the output is in the form of mechanical energy. Electrical engineers, however, not being satisfied with furnishing the facilities to our fellow engineers to develop their science, have gone a little further, and this evening we have listened to a paper on "Testing of Horizontal Lowhead Water Turbines." The paper is now open for discussion.

Mr. Andrus: The paper sets forth the method of test and is intended to show how it is possible to test water wheels in a fairly accurate manner. I also take up in the paper a discussion of why the Holyoke water power test would not necessarily prove what water wheels would do when installed in one of our industrial plants.

I think you will all agree with me in the statement that when a water power plant furnishing electric light and power is not commercially a success it is considered an example of poor engineering, no matter how well it operates. So the idea of testing these water wheels is really to get at the commercial side of water power plants as compared with steam plants. In commercial work it would be regarded as poor policy to develop a water power plant if one could build a steam plant and turn out electrical energy for less money. Where there are heads of 15 ft. to 20 ft., the American type of turbine described in the paper is supposed to be the most suitable. Plants on those low heads will cost about $250.00 per kw. by the time the development is completed. One has to provide his overflow land, and in localities where this is good farming land the price runs pretty high. The case is about the same as with a railroad company, namely, it will probably cost the company to buy up land for overflow about twice what it would cost an individual to buy land for a farm. For orchard land, one pays so much per tree; he cannot buy that land by the acre. We must allow at least 6% on our money, 3% for depreciation and some contingencies, and 1% for taxes, or 10% total. That would be $25.00 per year fixed charges on a water power plant, with an attendance of about $4.00 per kw. per year, or about $29.00 in all. It is not an exception to find a good, modern steam plant turning out current at ½c per kw. hour; 3000 watts per year would amount to $15.00 per year manufacturing cost. Such a plant costs about $100.00 per kw., with about 6% interest, say 6% depreciation, and 3% for taxes, contingencies, and so forth, or 15% total; and at $100.00 per kw. there would be $15.00 interest charges. That is, $15.00 manufacturing costs and $15.00 fixed charges will amount to $30.00 per kw. per year for the steam plant against $29.00 for the water power plant. So there is no appreciable advantages, under those conditions, from a monetary standpoint. I will cite an exception, however, to the above statements, based on some experience we have had: Suppose you build a steam plant; if somebody else comes along and builds a water power plant, you will have to buy him out in the end. So, as a matter of business policy in such a case, it might be better to develop the water power first and build the steam plant as needed.

There are a few things that cannot be figured in dollars and cents.

Wm. B. Jackson, M. W. S. E.: What governor did you use?

Mr. Andrus: We used the governor manufactured by the Lombard Company. It is not as yet a standard governor, but was made for these conditions. The governor head operating the governor ball and admitting the oil to this piston is the standard, but the piston and so forth working on this shaft moving back and forth have not been standardized.

To show what this means in a commercial way I have taken both a water power plant and a steam plant and plotted the cents per kilowatt with different percentages of load and different hours. For three hours the steam power is cheaper than water. For six hours, and nine hours—nine hours at 125% load—the water power is cheaper; also for twelve hours, 100% load, fifteen hours, etc. So one must have that long-hour service, fifteen and eighteen hours, before the water power comes into play at all, and that is due largely to the inefficiency of the wheel.

Mr. Jackson: How do you get 125% load on the water power plant?

Mr. Andrus: On this Elkhart development we cannot get 125% load, but on one of the other plants, where we get the full load at three-quarter gate opening, we can pull a 125% load. But the 125% load is very inefficient. On the Elkhart plant we get the efficient point at about 85% to 90% gate opening, by getting a certain load on the generators and gradually closing the gate until the generators commence to drop their load. So that with the minimum amount of water we get 90%, and all that we open the gate after that will not pull any more load and yet lets the additional water through. That is a very good feature for governing. Ninety per cent. will pull the full load, but the governor opens very suddenly. It has one-tenth oil pressure to cushion the governor on it. It goes clear to the end of the stroke to get the cushioning effect on the one-tenth.

This, so far as I have been able to find out, represents the best efficiency of any water power plant under the 18 and 20 ft. heads, although I think there has never been as complete a test as we have made. In talking with representatives of the companies manufacturing water turbines, I have not been able to find where they have gone into quite so much detail. We have tested two plants since testing this one, using water meters instead of a weir and taking the average of the water going into the wheel. In one plant we made a rigging that went right down where the head gates went with three meters, putting them inside of a guide that ordinarily carried the gates. So we obtained three readings in width and seven in elevation, one side, twenty-one readings. Then we put these meters in the same water that was measured going over the weir, and checked the accuracy of the meters against the accuracy of the weir and against the German meter. The meter gave a reading within ½ of 1% of what the weir measurements gave. We are testing two plants now with the water meters. It is absolutely necessary that the wheels be very efficient if one expects to compete with steam power, and it is necessary to retain that efficiency.

On steam prime movers, assuming that the economy of first-class triple expansion engines and turbines is about the same, 1 lb. of steam at 165 lb. pressure gives 2.72 cu. ft. One cubic foot at 28 in. vacuum has a volume of 249.7 cu. ft. That gives an expansion ratio of 100.

To have steam at 225 lb. pressure and 200 deg. superheat, we put it through a high pressure cylinder, then superheat it again, and put it through a low pressure cylinder.

Taking 2 lb. of coal as necessary to generate 1 kw. hour, burned with 200% of the theoretically correct air supply, we would have available in the flue gas 5880 B. t. u.'s of heat, with a flue gas temperature of 550 deg. Fahr. and with a temperature of the outside air of 100 deg. Fahr. Considering that under our assumed conditions we will not use very large units, we will take 15 lb. of steam for the prime mover as necessary to generate 1 kw. hour, and expand the steam down to the air pressure, 14.7 lb.; then we superheat the exhaust from the engine 100 deg. to the stack temperature and at this pressure we require practically 750 B. t. u.'s to re-evaporate 10% of condensation. This would require 1530 B. t. u.'s. Assuming that this would be done by passing the steam through pipes, around which the flue gases were passing, the flue temperature would then be lowered from 550 to 376 deg., leaving a difference in temperature between flue gases and outside air of 276 deg.

To condense the above statements: We raise the steam in the boiler to 225 lb. gauge pressure and give it 200 deg. of superheat before entering the engine. The steam is then expanded in the engine down to atmospheric pressure and passed through what might be termed a superheater placed in the path of the flue gases. In this superheater there is a re-evaporation of 10% and 100 deg. of superheat is added, this taking place at 14.7 lb. absolute pressure or starting at 212 deg. Fahr. Taking the total heat of 1 lb. of saturated steam at 225 lb. gauge pressure, and the heat in the water at 28 in. of vacuum or 1 lb. absolute pressure, and taking into consideration the B. t. u.'s for superheating once to 200 deg., and superheating a second time to 100 deg., and re-evaporation of 10%, we get, by combining these, an efficiency of 31%. If we take the combined efficiency of engine and turbine at 75%, we get an actual efficiency, in terms of the theoretical work in the steam, of 31% of 75%, which equals 23.2%, a figure which is just about double that which we are getting now as the thermal possibility in the steam plant.

Referring to Fig. 2, the little tubes in the forebay where the water is highest, can be seen connected through into the powerhouse. Those pipes are attached to glass tubes and so the water in the power house stands at the same height in the glass tubes as it does in the forebay outside.

There are some vacuum gauges tapped into the draft fixtures, so that in case we should not be realizing proper efficiency, the height of the mercury would show whether or not we had a solid column of water in the draft tube; but in this case our efficiencies were all right and we made no use of the mercury gauges.

Referring to the cross-section of the Holyoke test flume, the maker's guarantees are based on the efficiencies that we get from the Holyoke testing flume. That was probably where the first water wheel testing for efficiency standard was made, for the reason that at Holyoke they sell so much water to an individual, and he is welcome to all the power he can get out of it. Consequently everybody wants the most efficient wheel to get the most power for his money. Then the Holyoke people keep track of the amount of water that a man uses, by calibrating his wheel. They will put it in, and by running the water through at a certain speed, they know, with a certain gate opening and a certain speed, just how much water he is taking and their inspector goes around each day and gets the result, and sees that the gate is open just enough to get the amount of water for which the man is paying. In other words, the wheel is used as a water meter instead of a water wheel. At the same time, when they find out how much power a man has and how much water is going through the wheel, they have the figures for the efficiency, and the man who could get the most power out of a certain amount of water was the man who sold the most wheels. As a result, the different manufacturers would change the wheels to satisfy their customers and send them down to Holyoke to be tested.

In the paper I have called attention to why this Holyoke test would not necessarily prove just what a wheel would do when it was in position. It can be seen that the draft tube on the wheel at Holyoke is very short. In the case of the Elkhart plant we have a velocity head where the draft tube leaves the wheels, and then as it curves down and is expanded, the velocity becomes much slower and the difference in that velocity head becomes effective on the wheel and that depends on the length.

A test of a wheel was made at Holyoke, where, by shifting it up, 4 ft. was added to the draft tube length, thereby securing ½% increase in efficiency for each additional foot of draft tube. So we can see that if one has right draft tube conditions, it is possible to get a higher efficiency on the wheels than can be obtained at Holyoke, due to the draft tube conditions.

Another point is that when a wheel is discharging water vertically in the manner the water is thrown in the vertical test, one has no casing. Consequently wheels may test satisfactorily at Holyoke, with a badly designed casing, and work in a horizontal position so that the water from the top half of the wheel falls out and mingles with the water from the bottom half, but the wheel may develop 10% less power. In the Elkhart test we obtained 6% more power than the maker guaranteed, due to a gain in velocity head from the draft pipe, a thing which would not have obtained on the Holyoke test. I think at Holyoke they made an allowance; they reduced the Holyoke result for this point and at the high point on one unit we got back more than the maker expected. They secured 84% at Holyoke and guaranteed 80%; we secured, according to the chart, 83%, our gain being due purely to draft tube conditions and the design of the casing. It looks now, at other plants, as if it will pay to take off the top half of the cases and re-design them.

R. L. Sackett, Prof. Hydraulic Engineering, Purdue University, Lafayette, Ind.: Careful preparations were made in the original designs for this test in order to obtain the efficiency of the plant, and of the turbines.

The piezometer tubes in the headrace were well placed to give the elevation of the headwater. The water in each wheel pit was stilled to prevent vortices which also had the effect of making the gage readings more accurate.

The level of the tailwater was read from floats placed in tubes in the tailrace just below the mouth of the draft tube, judging from Fig. 2 of the paper. Whatever slight loss of head occurs at that point due to the change in cross section is uncertain, as the details of design are not shown, but such loss produces a decrease in the plant efficiency.

The most interesting feature was the construction of a temporary weir at the lower end of the tailrace by which to measure the discharge. The length and height of crest above floor are not given, but the length, about 80 ft., was several times that of any weir ever tested by accurate methods. It would have been interesting to know what coefficients were used, as the head on the weir was near that at which the coefficient is lowest as shown by the Bazin and Cornell experiments—about 0.411 in $Q=m\sqrt{2g}\,LH^{3/2}$ or $Q=3.296\,LH^{3/2}$.

The height of weir crest being also not stated, the method of correcting for the velocity of approach is unknown, but would be interesting.

On the whole, the apparatus for making the test was carefully set and the readings were scientifically taken. Credit is due the engineers and also the observers, a party of whom were seniors from Purdue University, for the results of this very interesting power plant test.

January, 1914

Mr. Andrus: With reference to the correction used on the weir, I will say that the United States Government has issued a publication on weirs and weir coefficients, and I used their standard method.

J. C. Pinney, Jr., ASSOC. W. S. E.: Realizing, as probably most engineers do, that there are certain limitations to tests on water wheels, as conducted at the Holyoke testing flume, such papers as this, dealing as it does with the tests of a water turbine under the actual conditions of running, are valuable contributions to the engineering profession.

The paper treats, with considerable detail, the preliminary steps by means of which the generator efficiency was determined, in order that the actual horse-power delivered to the generator shaft by the turbines might be accurately determined. From the precautions taken in determining this efficiency, it is evident that the data are reliable and that the true conditions were obtained as closely as possible. It is also evident, from the latter part of the report dealing with the method of making this particular test, that every precaution was taken and all errors eliminated as far as possible in taking the readings. The paper stops, in my opinion, just at the point where engineers dealing with water turbines would be desirous of taking it up, and I consider that the value of this paper can be very materially augmented if Mr. Andrus will add thereto some of the test data with their results. I sincerely hope that when the paper is published in the JOURNAL, data of at least some of these runs will be included. When we consider the carefulness with which the preliminary steps were taken, and the carefulness with which the test was evidently made, as is shown by the author's outline and system of taking readings, I think it is evident that the actual data obtained in this test will be reliable and therefore very valuable.

Mr. Andrus: I will say, with reference to Mr. Pinney's discussion, that up to the time the paper was published we did not have the computations finished, and we did not know whether or not the water wheel people would consent to our using the results. We wrote them to ascertain whether the results were such that they would be willing that we should give them out. The reply received was that they were not at all ashamed of the results of the test and gave permission to include the data in this discussion. The turbines were built by Leffel & Company, of Springfield, Ohio, and it can be seen that they have exceeded their guaranty for both units.

Mr. Jackson: I have been much interested this evening both in the paper and in the remarks of the author.

In a recent conference, to which I was a party, a discussion arose regarding the many water powers which have been developed and which have been commercially unsuccessful. The fact was brought out that in the determination of reasonable electric lighting and power rates for some cities under Commission control, which receive their electric supply from water powers, it has been necessary on the part of the Commissions to base the rates of charge for service upon the results that can be obtained from hypothetical steam-driven electric plants planned to supply the electric service for the cities under reasonable steam-generating conditions, owing to the exorbitant costs of service which arise from the consideration of the water-generating plants. This is a concrete illustration of the uncertainty of the value of water powers, whether developed or otherwise, and emphasizes the fact that the value of a water power can be determined only by a full knowledge of the conditions in each particular case. There is a surprising amount of water-power agitation throughout this country and there is unquestionably a wrong impression prevalent regarding the value of water powers of our country. Notwithstanding this comment, I consider that there is nothing finer than some of our splendid water powers, but it should be appreciated, especially in connection with lowhead powers and in connection with any water powers where the market is not already developed or is not in the immediate vicinity, that usually such powers can be developed only after the most careful study, if at all, if they are to be commercially successful. Thoughtful engineers of today ought to assist so far as they can the development of water powers where it is commercially practicable to develop them, since every such development adds just so much to the actual assets of the country, but they should bear in mind that many of the water powers now developed have been developed on account of ignorance or dishonesty and are not commercially successful. Anything which stops or checks the progress of the development of commercially valuable water powers is a positive detriment to the country, with the understanding, however, that there are doubtless, in many cases, certain governmental rights in the water powers.

There is another feature of water powers which is worth considering for a moment at this time: There are many water powers which, considered by themselves, are entirely worthless so far as commercial development is concerned, but which may be highly valuable as a unit in a property having a developed market for electric lighting and power, and using steam-generating equipment in coöperation with its water-power development or developments. Thus water power developments may be used in very effective combination with steam generation in such a way as to largely overcome the serious handicap of the low-water periods and flood-season periods of the stream flows. This was discussed in a paper I presented before the Society on March 4, 1903. Under such conditions it is frequently possible to develop water powers which otherwise would be quite impossible of commercially successful development. For this reason electric lighting and power companies which have unusual opportunity for effectively working water and steam developments in coöperation frequently find it possible to make successful use of water powers which would otherwise be worthless, and thereby bring about the truest kind of conservation of natural resources.

There is another thought worth considering here. The Holyoke testing flume has been in existence for thirty years. It was in existence for a number of years before the great electrical transmission developments became practicable, but so far as I can see the Holyoke flume has had relatively little to do with the wonderful improvement in the efficiency and character of American water wheels which has occurred during the past few years. This improvement is undoubtedly due to the remarkable development of the electrical generator and of electrical transmission possibilities and the consequent need for very large water wheels of highest efficiency, also on account of the fact that in hydroelectric power developments the amount of power being supplied by the water wheels is known at every moment and the efficiency or inefficiency of the water wheels is at all times prominently exhibited.

For example, I remember in the early days, in Canada, that of two fairly large hydroelectric plants, one was developing only about two-thirds as much electric power as the other from the same amount of water power, and under conditions of hydroelectric development this situation could not escape detection.

This paper is especially valuable on account of the fact that it gives us authentic information relating to a lowhead water wheel development, and I agree with Mr. Andrus that it is probably as efficient a lowhead development as can be found anywhere in this country. There might be some question as to such a statement if we include Europe, since there all of the water wheel manufacturers, up to a relatively recent date, have designed all of their water wheels for use under the exact conditions to which they were to be subjected. I believe I am correct in saying that in 1902 there was no water wheel manufacturer in Europe who made a line of standard water wheels. In other words, every water wheel was constructed for the particular work it was to do. This fact was impressed upon me as I happened to be at the Ganz Works in Buda Pesth at the time that they were developing a line of water wheels in accordance with the wheels manufactured by The James A. Leffel & Company, and at that time I understood they were about the first European manufacturers to consider the manufacture of a standard line of water wheels.

Another feature that seems interesting to me relating to this relatively small lowhead development is that the efficiencies of the water wheels as actually determined by the tests are within 1½% of the guaranteed efficiencies of reaction water wheels recently installed in a hydroelectric plant having high head and 10,000 kilowatt units.

Mr. Andrus: Mr. Jackson brought up the matter of European wheels. From an engineering standpoint, I think the European wheels are superior to American wheels, but from the standpoint of dollars and cents, Americans come out about the same place, because they save enough on the machinery.

There was a time when the water wheel became almost obsolete. In towns like Lowell, Massachusetts, where they had water power, the large industrial establishments first were built, because they had cheap power. Then as those plants grew and their product commenced to be marketed and shipped out, the transportation problem became of great importance, and the plants were moved to where there were proper transportation facilities. This removal of plants away from the water powers caused the latter to go bankrupt. There was no advancement in this line—at least affairs stood still—until the advent of the electric generator. That offered a solution to the problem, whereby plants could remain near the desired transportation facilities, and at the same time have the advantage of the water powers through the transmission of energy by means of electric generators. Consequently there has been a rejuvenation of water power development due, I think, to the possibility of transmitting power by means of the alternating current.

Dr. M. G. Lloyd: This paper offers a good illustration of how the progress in a great many branches of engineering depends upon the accuracy of electrical measurements. Tests of such prime movers as this can be much better carried out by making the load that of an electric generator and determining the load by electrical measurement. As Mr. Jackson has pointed out, such application has influenced and greatly helped the advance in the design of such prime movers; and the same thing is true, as well, in other fields.

Unfortunately, however, there is one point in which electrical measurements are still not quite as accurate as we might hope for. There are four sources of losses in the electrical generator, which have been taken up here by the author. Of those four, three can be very accurately determined; that is, the core loss, the bearing friction and windage loss, and the copper loss in the armature. Unfortunately, the fourth source, load losses, cannot be so accurately determined. In this paper a customary method has been followed in determining them; that is, the machine is run under short-circuit, and following the rule in the American Institute Standardization Rules, one-third of that quantity is taken as the proper loss to be figured. That method is a purely empirical one, which has been worked out as being a good enough general rule to apply in most cases. As a matter of fact, it is correct under certain circumstances and is not correct in others. The Standardization Rules of the Institute are now undergoing revision and I think probably that rule will be changed and it will not be found there in the next edition. I merely want to point out that this is simply an approximation and not an accurate determination, but it is about as good a rule as can be applied in general at the present time.

It will be noticed in Fig. 6 that the load loss is a very small quantity, so that its accurate determination is not a serious matter, and any inaccuracy involved there would not seriously affect the results obtained in these tests.

Mr. Andrus: The load loss curve in Fig. 6 is really taken as one-tenth of the copper loss and is not computed from taking one-third of the short-circuit core loss, but we did compute it the other way and the two were so nearly alike that I did not change the chart.

Mr. Roper: I should like to ask Dr. Lloyd if it would not be feasible to determine the load losses with some accuracy, if one had two generators, which he could use in testing separately by the Hopkinson method?

Dr. Lloyd: Yes, I think undoubtedly one could do that with two similar generators.

Mr. Andrus: In addition to the inaccuracy of the load loss, there is a little inaccuracy in the copper loss due to the difference in temperature. As the generator is under load the temperature gradually increases, which we computed at .25 deg. and at 40 and 60 deg., and it made only a fraction of 1% difference; so we did not take the temperature or even correct for it, the difference is so small.

L. F. Harza, Consulting Engineer, Portland, Ore.: The author has given in his paper a very clear exposition of the method used by him in the testing of a horizontal, open penstock, lowhead turbine installation.

These methods are quite usual except in regard to the method of measuring the water. In fact, it is seldom that the layout of a lowhead generating station is such as to permit the use of a weir for measuring the water without at least involving a great expense for its construction. For this reason lowhead installations using large volumes of water are seldom given a test after installation, and the profession thereby lacks very seriously any reliable data as to the operating results of turbine installations of this class where large volumes of water are used.

The author was fortunate in that his station layout contained a long rectangular tailrace in which a weir could be very cheaply constructed. The writer several years ago conducted a test on a similar installation, each unit consisting of six runners on horizontal shaft, under a head of 17 ft., discharging into a curved draft tube below and operating a 1500 kw. unit at 100 r. p. m. The station layout was such that the construction of a weir for measurement of the large volume of water would have been practically impossible except at great expense. The test was therefore made by thoroughly traversing the cross section of the penstock upstream from the turbines with carefully calibrated current meters. Each test extended over several hours and the meters were read almost continuously during this time, check observations being made 1 ft. apart vertically and 20 in. apart horizontally, over the entire cross section of the flowing water, which was 20 ft. deep and 40 ft. wide. The position of the meters was controlled by vertical wires previously installed in the penstock and spaced 20 in. apart across the entire width. This test was only for general information and its accuracy was no doubt lower than the accuracy obtained by the author at Elkhart. The runners had been previously tested at Holyoke, but the test in place was not sufficiently elaborate to form a basis for studies as to the relative efficiency in place and in the Holyoke flume.

Since that time the writer was connected with the design of a hydroelectric station in which the turbine layout, type and form of draft tubes, appear to have been the same as at Elkhart. The installation is not yet ready for test. The runners are 60 in., which are too large for test at Holyoke, and an accurate test in place would be very difficult because the station layout offers no opportunity for the installation of a weir.

The author's test at Elkhart appears to have been very carefully made and if correlated with a test of the same runners at Holyoke, a comparison of the results would be of inestimable value to the profession. He does not state whether or not these runners were tested at Holyoke, but whether they were or not it is very greatly to be regretted that he has confined his remarks almost exclusively to the method of conducting the test, which on the whole is very usual, and has failed to incorporate in his paper any appreciable data showing the results obtained by him under the various operating heads with which he was working.

Even had the runners not been tested at Holyoke, it is probable that homologous runners made by the same manufacturer have been so tested, and a detailed comparison of the test results of the 50 in. quadruplex unit after installation, with the test results of a homologous runner of another size in the Holyoke flume, would be of great value in indicating the degree of accuracy, and direction and approximate magnitude of the error involved in predicting from a Holyoke test of one runner, what operating results may be expected from a homologous runner of the same or different size when installed in twin units under conditions similar to those at Elkhart. The hydroelectric engineer is continually called upon to make this prediction and the available data for guiding his judgment in this matter is almost *nil*. It is to be hoped that the author in a later paper will present this data and make some comparisons of the nature indicated.

January, 1914

APPENDIX

LOG OF TEST FOR 50 IN. HORIZONTAL LOWHEAD WATER TURBINES AT ELKHART, INDIANA

IN GENERAL

The engineer in charge of such a test as described in the paper stands in a position between the individual or corporation desiring the test to be made, and the contractor who furnishes the apparatus and accessories which are to be tested. The test is usually made to the end that certain guarantees, under which the apparatus was furnished, might be verified, and usually the contract contains some penalty upon the contractor, should the apparatus not meet such guarantees. It therefore devolves upon the engineer to make sure that those who retain him receive an honest and fair return for their money, and while it is true that he is employed by only one of the parties to the contract, he should endeavor to see that fairness to both parties of the contract is secured. The engineer's decisions are usually final, unless it can be shown that actual fraud exists. If such can be shown, then the test may be the cause of litigation in the courts. Again, should the apparatus and accessories under test not meet the guarantees, the contractor might claim that the test, as conducted, was not one which would truly serve the purpose for which it was intended, and under such an allegation he has the right to make the test a cause of litigation to prove the insufficiency of the test.

To avoid such litigation, it is better that a written description defining the methods of test and the methods of computing results from the test be prepared by the engineer for the approval of the individual or corporation having the work done, and for the approval and guidance of the contractor doing said work. Such a written document should be embodied with and be made a part of the specifications and contract, and they should fix definitely the fact that such a test, when properly conducted, shall be acceptable to both parties to the contract. In other words, when the engineer believes that to attain the best results the test must be performed in some particular way, it is necessary to incorporate the method of test in the specifications. This being done, it must be remembered that under these circumstances the contractor cannot be held responsible for the mistakes of the engineer. Therefore, when the engineer specifies that the test shall be made in a certain way, he must assume the responsibility and bear in mind that the test may become a cause of litigation in the courts. Under such conditions his methods and computations, as noted during the test, will be introduced as evidence, and the engineer must be able to substantiate the correctness of them, also the methods used in computing final results from the reading as noted on his test log. The writer, in submitting such a test log, does not wish to stand in the position of stating that it is infallible, but hopes that it may be the means of helping to advance, in the engineering profession, what will in the future be a very important line of work.

INTERPRETATION OF LOG SHEETS—ELKHART WATER WHEEL TEST.

LOG SHEET NO. 1

Miscellaneous Data.

Column 1. Run numbers are assigned in the order of sequence in which the different tests were made. This column is repeated on all sheets to facilitate comparison.

Column 2. The number assigned, for the purpose of test, to the unit upon which the individual test was made.

Column 3. The day upon which the test was run. This is important to the end that all conditions under which the test was conducted be made a matter of record for the reason that the test may be made the cause of litigation.

MISCELLANEOUS DATA LOG SHEET 1									
1	2	3	4	5	6	7	8	9	10
		TIME INCLUSIVE			TEMPERATURE DEGREES FAR.		REMARKS		
Run No Observed	Unit No. Observed	Date - 1913 Observed	Begining of Run Observed	End of Run Observed	Atmosphere Observed	Water Observed			
3	1	June 4	A.M. 9:37	A.M. 9:46	63½	69½	No Wind		
4	1	"	10:03	10:12					
5	1	"	10:51	11:00			Clear		
6	1	"	11:14	11:23					
7	1	"	11:34	11:43					

Column 4. The hour and minute when the test was begun. This is important to the end that all conditions under which the test was conducted be made a matter of record for the reason that the test may be made the cause of litigation, and for the additional reason that in working up results it is necessary to identify the simultaneous readings at each of the 17 stations when making up the composite log of the test.

Column 5. The hour and minute that the test was completed. This is important to the end that all conditions under which the test was conducted be made a matter of record for the reason that the test may be made the cause of litigation, and for the additional reason that in working up results, it is necessary to identify simultaneous readings at each of the 17 stations.

Column 6. Temperature of the atmosphere as observed by a Fahrenheit thermometer just outside of the power house. This is important to the end that all conditions under which the test was conducted be made a matter of record, for the reason that the test may be made the cause of litigation.

Column 7. Temperature of the water in the pond as observed by a Fahrenheit thermometer. This is important to the end that all conditions under which the test was conducted be made a matter of record, for the reason that the test may be made the cause of litigation.

WATER TURBINE DATA LOG SHEET 2

1	11	12	13	14	15	16	17	18	19
	GATE		R.P.M.			VACUUM HEAD			
	OPENING					IN FEET			
						MERCURY GAGE			
Run No.	Inches opening from Calibration curve	Per Cent opening Observed on Gate Scale	Maximum Observed	Minimum Observed	Average (Sum of readings) ÷ (No. of readings)	Gages #31 and #32 on Unit #1 observed	Gages #33 and #34 on Unit #2 observed	Static Head. Elevation (Tapping point Vac. pipe)-(El. of Tailwater {col. 39})	Vac. head as % of static head (col. 16) ÷ (col. 18) x 100
3	7.10	100%	129	124	125	1.70	0.79	.922	184.5%
4	6.50	93%	126	124	125	1.47	0.79	.990	148.5%
5	5.60	885%	122	118	119.5	1.24	0.68	1.114	111.5%
6	4.45	69%	121	117	119.6	1.36	0.79	1.357	100.4%
7	3.25	55%	122	119	120.0	1.92	0.68	1.650	116.4%

Columns 8, 9 and 10. The columns are for general remarks of the weather, and abnormal conditions influencing the test. This is important to the end that all conditions under which the test was conducted be made a matter of record for the reason that the test may be made the cause of litigation.

LOG SHEET NO. 2

Water Turbine Data.

Column 11. Gate opening in inches is taken from a curve in which the gate opening was actually calipered and measured in inches, then plotted together with the indicated opening on the governor scale. (See Fig. 12.)

Column 12. Gate opening as actually observed on the governor scale for each run.

Column 13. The revolutions per minute are observed on the tachometer each minute during the run, and in this column is noted the maximum revolutions per minute observed during the individual run.

Column 14. The revolutions per minute are observed on the tachometer each minute during the run, and in this column is noted the minimum revolutions per minute observed during the individual run.

Column 15. This column is the average of the revolutions per minute as noted each minute during the individual run.

Column 16. Vacuum head in feet was obtained by reading the difference in elevation of mercury in a glass U tube, in inches, then reducing the mercury head in inches to the equivalent head of water in feet, by multiplying the mercury head in inches by 1.127, obtained as follows: Divide 0.489, the weight per cubic inch of mercury, by 0.0362, the weight per cubic inch of water, and then divide the result by 12 to reduce the head to feet. The reading noted is the average of readings taken each minute during the run. Gages No. 31 and No. 32 read the vacuum head on the unit that is under test. The action of the mercury in the U tubes will indicate the draft tube conditions, should the same not be normal.

Column 17. This column is similar in every way to Col. 16, except that gages No. 33 and No. 34 are on the idle unit. The reading noted is the average of readings taken each minute during the run. The action of the mercury in the U tube of the idle unit will indicate whether or not the water in the tailrace is being taken away freely or if it tends to back up in the draft tube at the downstream side of the power house.

Column 18. This column is the static head as measured by the difference in elevation of the point of gage tapping in the draft chest and the tailwater on the turbine.

Column 19. Vacuum head as per cent. of static head is the vacuum head in feet divided by the static head in feet, multiplied by 100 to give per cent. The difference between the simultaneous reading in Cols. 16 and 18 represents the velocity head which is made up of two components, the straight velocity and the tangential velocity.

LOG SHEET NO. 3

Francis Weir Data.

Column 20. The water over the weir was read by means of hook gages, the zero of the hook being set at exactly the same elevation as the crest of the weir; thus the hook gage reads directly the amount of water passing over the weir. The hook gages were set in barrels connected to the tailrace at points 30 ft. upstream from the weir. Gage No. 1 reads the water flowing over the weir 2 ft.

from the left tailrace wall when looking downstream. The reading noted is the average of readings taken each minute during the run.

Column 21. The reading noted is taken the same as No. 1, except that it is 28 ft. from the left tailrace wall looking downstream.

Column 22. The reading noted is taken the same as No. 1, except that it is 54 ft. from the left tailrace wall looking downstream.

Column 23. The reading noted is taken the same as No. 1, except that it is 80 ft. from the left tailrace wall looking downstream.

Column 24. This column is the average of the four hook gage readings and is the figure used in computing the flow over the weir.

FRANCIS WEIR DATA LOG SHEET 3

1	20	21	22	23	24	25	26	27	28	29	30	31	32
	WATER OVER WEIR					DISCHARGE PER FOOT							
Run No.	Left No. 1 Observed by Hook gage	⅓ point #2 Observed by Hook gage	⅔ point #3 Observed by Hook gage	Right #4 Observed by Hook gage	Averages of Cols. 20-21-22-23 Mean of the 4 Hook gage readings.	Qa from Weir tables. per foot of length	Area of Channel measured 28' up stream from Weir	Vel. of approach (Col. 25) ÷ (Col. 26)	Per cent of increase from Weir tables	Qa Final (Col. 25)x(Col. 28+100) per foot of length.	Tail water on weir observed on board gage	Q1 Total weir discharge L = 88.58' Q1 = (Col. 29)x(88.58')	El. Head water on Weir = (El. 81.00) + (Col. 24)
3	2.138	2.110	2.106	2.105	2.114	10.235	17.891	.57	.4 %	10.27	79.7	848	83.114
4	2.059	2.037	2.026	2.031	2.038	9.688	17.815	.54	.4 %	9.74	79.7	804	83.038
5	1.917	1.899	1.892	1.899	1.902	8.735	17.679	.49	.3 %	8.77	79.1	724	82.902
6	1.648	1.632	1.627	1.629	1.633	6.949	17.410	.40	.2 %	6.96	78.8	574	82.632
7	1.339	1.329	1.325	1.327	1.330	5.108	17.107	.30	.2 %	5.18	78.7	423	82.330

Column 25. Q_a, the flow over the weir by Francis formula, was obtained from standard weir tables, by knowing the kind of crest and the head upon the same. (See U. S. Geological Survey Publication, Water Supply & Irrigation Paper No. 200, page 162.)

Column 26. The cross-sectional area of the channel of approach 28 ft. upstream from the weir, was obtained as follows:

(a) The width was actually measured before the water was turned in.

(b) The height is the difference between the elevation of the floor of the tailrace and the crest of the water at the time the run was under way.

Column 27. The velocity of approach was figured by the formula $V = Q_a/A$, in which the discharge Q_a (Col. 25) and the cross-section area A (Col. 26) are known.

Column 28. The per cent. of increased discharge in excess of Q_a due to velocity of approach, was obtained from standard tables. (See U. S. Geological Survey Publication, Water Supply & Irrigation Paper No. 200, page 160.) Knowing the velocity of approach (Col. 27) and the head flowing over the weir (Col. 24), the percentage increase can be taken directly from the tables.

Column 29. The total discharge per foot of length of weir crest is obtained by multiplying the discharge Q_a (Col. 25) by the increase in per cent., as noted in Col. 28, plus 100.

Column 30. Tailwater on the weir was read directly on a gage board set to dam datum on the downstream end of the left tailrace wall, 48.4 ft. downstream from the weir. The reading noted is the average of the readings taken each minute during the run.

Column 31. Total weir discharge is the discharge per foot of length of weir crest (Col. 29) multiplied by the total length of the weir crest (82.52 ft.).

Column 32. Elevation of headwater on the weir is obtained by adding the average height of water over the crest of the weir as read by hook gages (Col. 24) to the elevation of the crest of the weir (Elevation 81.00).

LOG SHEET NO. 4

Operating Head Data.

Column 33. Pond gage No. 29 was a piezometer gage, reading headwater elevation, directly to the dam datum. The reading noted is the average of readings taken each minute during the run.

Column 34. Gage No. 23 was a piezometer gage, reading headwater elevation in the penstock at the left side of the unit under test and midway between the two draft chests. The reading noted is the average of readings taken each minute during the run.

Column 35. Gage No. 24 was a piezometer gage, reading headwater elevation in the penstock at the right side of the unit under test and midway between the two draft chests. The reading noted is the average of readings taken each minute during the run.

Column 36. This column is the average of the two headwater elevations on the unit under test as noted in columns No. 34 and No. 35.

Column 37. This column gives the elevation of tailwater at the downstream side of the power house in the left downstream draft tube as read by float gage No. 12 set to dam datum. The reading is the average of readings taken each minute during the run.

Column 38. Gage No. 13, reading noted, is taken the same as gage No. 12, except that it is placed on the right upstream draft tube of the unit under test. The reading noted is the average of readings taken each minute during the run.

Column 39. This column is the average of the two float gage tailwater elevations on the unit under test, as noted in Cols. 37 and 38.

Column 40. The operating head on the turbine under test is the difference in elevation, stated in feet, between the headwater (Col. 36) and the tailwater (Col. 39).

Column 41. This column gives the variations in the elevation of the tailwater at the wheels and 30 ft. upstream from the weir, and is obtained by taking the difference between the tailwater elevations at the stated locations.

Column 42. The rack loss is the loss in head due to the friction and increased velocity of the water passing through the racks, and is obtained by taking the difference in water elevation upstream from the racks (Col. 33) and water elevation in the penstock under test (Col. 36).

OPERATING HEAD DATA LOG SHEET 4

1	33	34	35	36	37	38	39	40	41	42	43	44
	HEAD BY PIEZOMETERS				TAIL WATER FLOAT GAGES							
Run No.	Pond gage #89	Left gage #83 over unit #1	Right gage #84 over unit #1	Average of Gages (Col. 34 #83) and (Col. 35 #84)	Left down stream draft tube #18	Right up stream draft tube #13	Average of gage (Col. 37 #18) and (Col. 38 #13)	H. Head on the Turbines (Col. 36) − (Col. 39)	Difference in tailwater at Wheel and Weir (Col. 39) − (Col. 38)	Rack loss (Col. 33) − (Col. 36)	Pen. Vel. at sill (Qs [Col. 48]) + (Area at sill)	Rack loss as % of total test head. (Col. 42 ÷ Col. 40) x 100
3	96.345	96.186	96.187	96.186	83.069	83.087	83.073	13.113	−.041	.159	2.42	1.21 %
4	96.281	96.147	96.139	96.143	82.991	83.019	83.005	13.138	−.033	.138	2.31	1.05 %
5	96.290	96.161	96.166	96.164	82.882	82.880	82.881	13.283	−.021	.126	2.08	.95 %
6	96.324	96.248	96.244	96.246	82.642	82.634	82.638	13.608	+.005	.078	1.63	.57 %
7	96.367	96.326	96.326	96.326	82.365	82.335	82.345	13.981	+.015	.041	1.20	.29 %

Column 43. The penstock velocity at the tainter gate sill, downstream from the racks, is found by the formula

$$V = \frac{Q_5 + \frac{1}{2} Q_4}{A}$$

in which $Q_5 + \frac{1}{2} Q_4$ (Col. 48 + ½ Col. 47) is the total water passing, and A is the cross-sectional area at the sill, obtained as follows:

Column 43. (a) The width was obtained by actual measurement before the water was turned in.

(b) The height is the difference between the elevation of the gate sill and the crest of the water at the time run was under way.

Column 44. The rack loss as per cent. of the total net head is obtained by dividing the rack loss in feet (Col. 42) by the total head in feet (Col. 40) and multiplying by 100 to give per cent.

LOG SHEET NO. 5

Reduction Factors.

Column 45. Leakage through the weir was obtained by sealing the drain valves with cinders and reading the loss of head on the weir during a fixed period of time, after the water fell below the crest. Then, knowing the area of the tailrace, above the weir, the cubic feet of water lost for the stated time could be computed. Then by dividing the cubic feet loss by the stated time in seconds, the leakage in cubic feet per second is obtained.

REDUCTION FACTORS LOG SHEET 5

1	45	46	47	48	49	50	51	52	53	54	55
	LEAKAGE UNITS IDLE										
Run No.	Q_2 Leakage through Weir separate test	Q_3 Leakage through closed openings (assumed)	Q_4 Total leakage thro. both turbine gates when closed (separate test)	Q_5 Effective water thro. unit under test $(Q_1\ Col.31)+(Q_2\ Col.45)-(Q_3\ Col.46)-(\frac{1}{2}Q_4\ Col.47)$	H. from Col. 40	$H^{\frac{3}{2}}$	$\sqrt{H}$	$\frac{R.P.M.}{\sqrt{H}}$	$\frac{120}{\sqrt{H}}$	$\frac{Q_5}{4\sqrt{H}} = \frac{Col.\ 48}{4\sqrt{H}}$	$\frac{H.P._8}{4H^{\frac{3}{2}}} = \frac{Col.\ 61}{4H^{\frac{3}{2}}}$
3	4	2	12	844	13.113	47.49	3.621	34.6	33.2	58.2	4.85
4	4	2	12	800	13.138	47.62	3.625	34.6	33.1	55.2	4.85
5	4	2	12	720	13.283	48.40	3.644	32.8	32.9	49.3	4.63
6	4	2	12	570	13.608	50.19	3.689	32.4	32.5	38.6	3.54
7	4	2	12	419	13.981	52.27	3.739	32.1	32.1	28.1	2.32

Column 46. The leakage through the closed openings of the exciter and future unit penstocks was assumed after a careful inspection by the test engineer, his judgment being based on previous tests.

Column 47. Total leakage through the two units when the turbine gates were closed was obtained by reading the amount of water flowing over the crest of the weir after the head on the weir became constant. This total discharge over the weir, plus the leakage through the weir (Col. 45), less the assumed leakage through the closed openings (Col. 46), gave the total leakage through the gates of the two units. The leakage for one unit would be one-half of such total.

Column 48. The effective water through the unit under test is the actual water that passes through the turbine gates of the unit under test, less the hydraulic leakage of that unit, which is one-half Q_4, (½ Col. 47), which is equal to the total water over the weir (Col. 31), plus the weir leakage (Col. 45), minus the hydraulic leakage (½ Col. 47) through the unit under test, minus leakage through all closed openings (Col. 46).

Column 49. Feet of head in this column is the same as mentioned before in Col. 40, re-stated at this point for convenience.

Column 50. The operating head to the three halves power is noted for the reason that the horse power output varies as the head to the three halves power.

Column 51. The square root of the operating head is noted for the reason that the discharge varies as the square root of the head.

Column 52. Actual unit revolutions per minute at 1 ft. head are the actual revolutions per minute (Col. 15) divided by the square root of the working head (Col. 51).

Column 53. Normal revolutions per minute at 1 ft. head are the normal revolutions per minute (120) divided by the square root of the working head (Col. 51).

Column 54. Unit discharge per water turbine is computed by dividing the effective water discharged (Col. 48) by the number of water turbines and by the square root of the operating head (Col. 51).

Column 55. Unit horse power is the horse power developed by one water turbine assumed to be operating at 1 ft. head, and is computed as follows: Divide the total horse power developed (Col. 68) by the number of water turbines under test, and by the operating head to the three halves power (Col. 50). (See Fig. 11.)

Note: The reduction to unit basis curve, as noted in Columns 53, 54 and 55, is for the purpose of comparing water wheel characteristics on the same basis, and from such unit curves the characteristics at different operating heads may be predetermined.

LOG SHEET NO. 6

Electrical Data.

Column 56. Indicated volts are read on a voltmeter connected to the line through a potential transformer. The reading noted is the average of readings taken each minute during the run.

Column 57. Indicated amperes are read on an ammeter connected to the line through a current transformer. The connections were so arranged that the amperes could be read on each phase. The reading noted is the average of readings taken each minute during the run.

Column 58. Reading wattmeter No. 1. Indicated watts are read on two wattmeters so connected that the sum of the readings of the two wattmeters, when corrected for current and potential transformer ratios, gave a true reading of the actual kilowatt output of the generator.

Column 59. Reading wattmeter No. 3. Indicated watts are read on two wattmeters so connected that the sum of the readings of the two wattmeters, when corrected for current and potential transformer ratios, gave a true reading of the actual kilowatt output of the generator.

Column 60. Actual line volts as computed from Col. 56, by multiplying by the potential transformer ratio 59.5-1.

Column 61. Actual terminal amperes as computed from Col. 57, by multiplying by the current transformer ratio 24.75-1.

Column 62. Total kilowatt output is equal to one-half the sum of Col. 58 plus Col. 59 multiplied by the product of the potential transformer ratio and the current transformer ratio, or (59.5×24.75). One-half the sum is used for the reason that the wattmeter scale read double.

ELECTRICAL DATA LOG SHEET 6

1	56	57	58	59	60	61	62	63	64	65	66	67	68
			INDICATED WATTS					LOSSES IN K.W				INPUT TO GENERATOR	
Run No.	Indicated Volts observed	Indicated Amperes observed	Wattmeter #1 observed	Wattmeter #3 observed	Line Volts. Col. 49 corrected for transformer ratio	Terminal Amperes Col. 60 corrected for transformer ratio	Total K.W. output (Col. 51)+(Col. 58) corrected for transformer ratio	Core loss from Gen test sheet	Copper loss cal. from Gen. test sheet.	Load loss cal. from Gen. test sheet	Friction and Windage loss from Gen. test sheet.	K.W. input to Generator Cols. 55+56+57+58+59	H.P.s (Col. 60) × $\frac{1000}{746}$
3	64.25	4.040	442.0	456.0	3825	100	660	16.5	5.8	0.6	5.0	687	920
4	63.80	4.080	444.0	457.0	3800	101	662	15.5	6.0	0.6	5.0	689	922
5	59.60	4.240	432.0	445.0	3560	105	645	13.0	6.5	0.7	5.0	670	898
6	52.00	3.870	343.5	351.5	3100	96	511	10.0	5.4	0.5	5.0	532	713
7	54.70	2.500	227.0	243.5	3260	62	345	11.0	2.3	0.3	5.0	364	488

Column 63. The core loss for each different load was computed from the data obtained from the factory test sheets of the generator, under test at the voltage noted in Col. 50.

Column 64. Copper loss for each run is computed from the resistance as given on the factory test sheet and the amperes as noted in Col. 61.

Column 65. The load loss was computed in accordance with the A. I. E. E. Standardization rule (See Transactions, Vol. 30, Part 3, page 2549).

Column 66. The friction and windage loss, as taken from the factory test sheets of the generator.

Column 67. Total kilowatt input to the generator is the sum of the kilowatt output plus all the losses in kilowatts.

Column 68. Total horse power input to the generator is equal to the kilowatt input when multiplied by 1000 and divided by 746

LOG SHEET NO. 7

Computed Efficiency.

Column 69. Generator efficiency in per cent. equals the output in kilowatts divided by the total imput in kilowatts, multiplied by 100.

COMPUTED EFFICIENCY LOG SHEET 7

1	69	70	71	72	73	74	75	76	77	78
			WATER TURBINE EFF.				HOLYOKE EFFICIENCY AT TEST HEAD			
				GUARANTEED AT TEST HEAD						
Run No.	Generator Efficiency (Col. 65) ÷ (Col. 60) × 100	H.P. Theoretical H.P. = (Qs × H) ÷ (8.82)	Actual Efficiency $\frac{H.P.2}{H.P.}$ (Col. 61) ÷ (Col. 63) × 100	At normal R.P.M. from guarantee	Actual as R.P.M. from guarantee	Actual as % of guarantee (Col. 64) ÷ (Col. 66) × 100	Actual R.P.M. from Holyoke test.	Normal R.P.M. from Holyoke test.	Discharge as % of Min. Water at Max. capacity at test head (Col. 54) ÷ (56.2)	Plant Efficiency (Col. 68) × (Col. 64)
3	96.1%	1255	73.2%	73.2%	73.2%	100 %	81.50%	81.8%	105.4%	70.3%
4	96.1%	1191	77.3%	78.0%	78.0%	99.2%	84.20%	84.2%	100.0%	74.5%
5	96.2%	1082	82.8%	81.1%	81.3%	101.8%	86.55%	86.4%	89.6%	79.6%
6	96.0%	880	81.0%	79.0%	79.0%	102.6%	82.30%	82.4%	70.0%	77.7%
7	94.8%	644	72.4%	71.3%	71.4%	103.1%	77.60%	77.4%	51.0%	69.2%

Column 70. Theoretical horse power is equal to the product of the effective water discharged in cubic feet per second (Col. 48) multiplied by the head (Col. 40), multiplied by 62.5 (the weight of a cubic foot of water) divided by 550 (the number of foot pounds of work per second equivalent to one horse power).

Column 71. The actual efficiency of the water turbine is equal to the actual horse power delivered to the generator (Col. 68) divided by the theoretical horse power (Col. 70), multiplied by 100 to give per cent.

Column 72. This column is the maker's guaranteed efficiency in per cent. at normal revolutions per minute reduced to actual test head. This was done by interpolating between the guaranteed efficiency curves for 13 ft. and 14 ft. head.

Column 73. This column is the maker's guaranteed efficiency in per cent. reduced to actual revolutions per minute and test head. This was done by interpolating between the guaranteed efficiency curves for 13 ft. and 14 ft. head and also interpolating between the guaranteed efficiency curves for 128 revolutions per minute and normal revolutions per minute.

Column 74. Efficiency from test (Col. 71) as per cent. of guaranteed efficiency (Col. 73) is the test efficiency divided by the maker's guaranteed efficiency multiplied by 100 to give per cent.

Column 75. Holyoke efficiency at actual head and revolutions per minute as tested in the Holyoke testing flume.

Column 76. Holyoke efficiency reduced to normal revolutions per minute (120) under actual test head as tested in the Holyoke testing flume.

Column 77. Unit discharge in per cent. of unit minimum water at maximum capacity is the unit discharge of Col. 54 divided by the minimum water at maximum capacity (55.2 cu. ft. per second) multiplied by 100 to give per cent.

Column 78. The total plant efficiency is the product of the generator efficiency in per cent. multiplied by the water wheel efficiency in per cent.

THE GRAND STAND FOR THE UNIVERSITY OF CHICAGO

CHARLES HODGDON, ARCHITECT.

Presented before the Bridge and Structural Section October 13, 1913.

During the last 25 years there has been, without much doubt, a revival of interest in athletic games and contests which, for comparison, we must refer back to Rome and Greece. During the middle ages tournaments and contests were carried on, of course, to some extent, but I do not recall any such permanent structures having been built for the use of spectators for such sports, as were built in ancient times or during the past few years.

At the present time, nothing has been built as large, splendid, and imposing as the Colosseum of Rome or the Amphitheatres in the Roman provinces. The Greek Stadia are the oldest of these structures and the name came from the word stadium, the length of the foot-race, which was 606 ft. 9 in. English measurement.

It is supposed that in the beginning these contests took place in natural hollows with the spectators seated on the hillsides. Later these natural hollows were shaped and then provided with seats of marble laid directly on the ground, as in the Stadium at Athens. In some cities, the seats were supported by masonry.

The Stadium at Athens was arranged in the following manner: The lower tier of seats was raised 3 ft. above the arena. About 6 ft. in front of this lower tier a breastwork formed a separation between the bank of seats and the arena. The space thus cut off served as a passage to give access to the steps leading to the seats. The passage and the arena were underdrained, and there were underground entrances, leading to the arena, for the contestants and judges.

The Athens structure was built, it is believed, about 350 B. C. About 500 years afterwards, a wealthy Roman added seats of marble, but during the decay of the Roman Empire the structure lost nearly all of its marble work and was nearly buried. Since 1869 it has been excavated and completely restored and is now used for the Olympic games.

Like many of the Greek Stadia, the structure was built like a horse shoe, semi-circular at one end and open at the other. The Stadium at Harvard was built on this plan, and seats 20,000 people. The Athens Stadium had a seating capacity of 50,000. The Colosseum at Rome had a seating capacity of 80,000. The Circus Maximus at Rome seated 380,000. The Grand Stand that I am to describe seats less than 9,000 and is, therefore, a tiny affair.

The Romans developed this Amphitheatre and Circus from the Greek Stadium or Theatre. Their structures were generally built on a level site; the tiers of seats were supported on arches and vaults of masonry, and the space below the seats was utilized for passages and stairways, and for other purposes.

The Roman Circuses were at first used mainly for horse and chariot races; their Amphitheatres were used for gladiatorial combats; and in the Colosseum it is known that water was admitted to the arena when sham naval combats were fought with triremes.

With the downfall of Rome athletic contests ceased. But in recent years there has been a revival of outdoor sports, especially at our colleges, and for a number of years now no regularly-occurring events are followed with such universal interest and collect such large crowds as the athletic contests between the large colleges. Consequently a demand has arisen for a type of structure with large seating capacity and of enduring material, free from fire risk. This demand has resulted in the modern Stadium and Grand Stand, built with the Greek and Roman models in mind, and suitable to withstand a colder climate. Architects have found reinforced concrete best suited for the requirements.

The first concrete Stadium in the United States was built for the University of California in 1903. Though called a Stadium, it is on the lines of a theatre. The next larger and more important Stadium is at Harvard College, built in the same year. This followed the plan of the old Greek Stadia, but suggested the Colosseum in appearance.

The third structure is at Syracuse (N. Y.) University. In plan this is oval with semi-circular ends, and was built in a large, natural hollow connected at one end with the Gymnasium. There is an elevated walk 4 ft. wide protected by a curb running around the arena. Above this rise 18 tiers of seats to the upper ground level. Surrounding the top tier of seats, is a promenade 20 ft. wide, at the natural grade: at its outer edge there is an iron fence. The spectators arrive at this level, pass through gates to the promenade, and then descend the aisles to their seats.

At the Stadium in Syracuse and the one at Harvard the spectators are obliged to sit on the concrete tread, which is, I believe, a dangerous thing to do, especially in the late fall when football games are played.

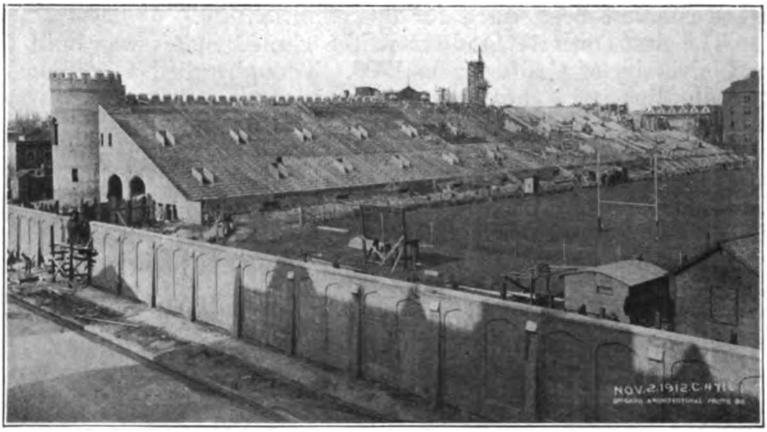
At Harvard, they modify this to some extent by laying planks directly on the concrete treads for the spectators to sit on.

Since the Stadia at Harvard and Syracuse were built, several stands for baseball parks have been built, which show a distinct advance in seating accommodations. A plank is raised some 3 or 4 in. on a casting or steel shape, thus raising the spectator and giving the person behind toe space under the plank. The fact that there is more frequent use of baseball stands than college stands is leading owners to provide better accommodations.

An examination of the Stadia at Harvard and Syracuse showed the interesting development that in spite of all the care taken to prevent it, expansion and surface cracks progress rapidly. The

Stadium at Harvard is leaking badly and at no very distant date it will need to be largely reconstructed. A portion of the Stadium at Syracuse has a roof covering, and it was noticed that under this there were practically no surface cracks, while out under the open sky the intense heat of the summer sun had resulted in considerable havoc; large pieces had scaled off, necessitating some patch work. In spite of these examples and all the care we could take, I am not sure that the Chicago Stand will not follow its illustrious examples.

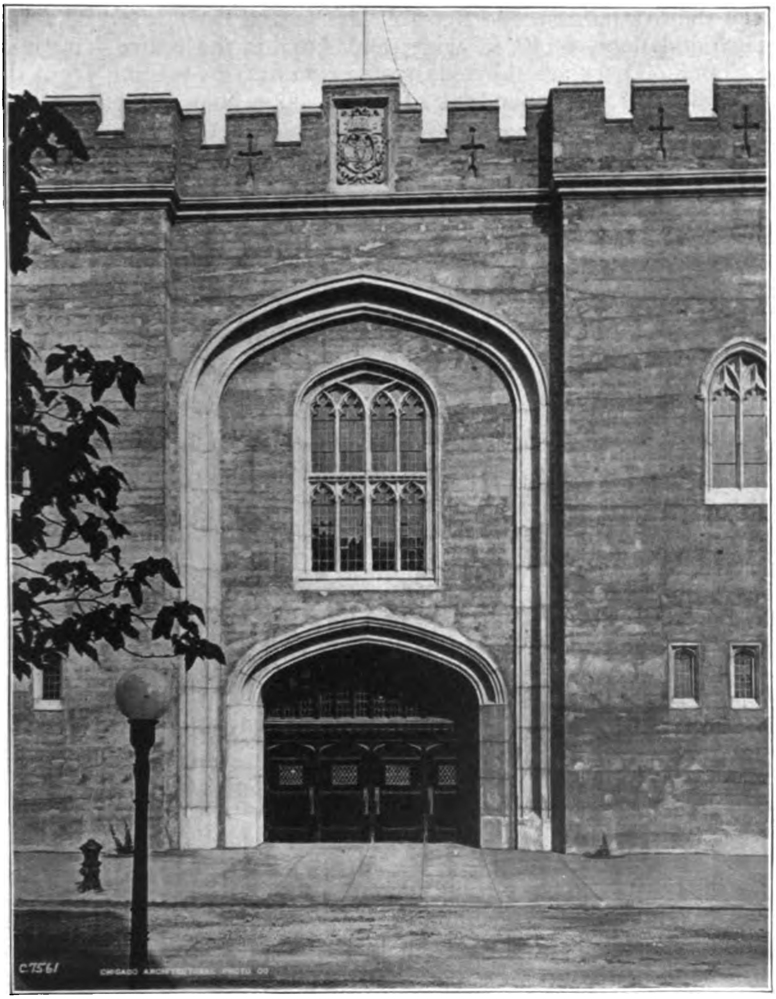
It has been the practice of the authorities of the University of Chicago to use the Gothic style of architecture in all their buildings, and consequently no departure from that practice was considered when the Grand Stand was designed. It was hoped that it might be appropriate, in planning this stand, to follow the plan of the feudal castles of the Norman Period in England, and not to forget that as time went on window openings were cut in the solid walls and filled with tracery and glass. It is hoped that the towers and battlements may recall to mind and, perhaps, strengthen, the memories of olden days. At the same time it was desired to surround the athletic field with a wall, which was also done.



Grand Stand and Enclosing Wall.

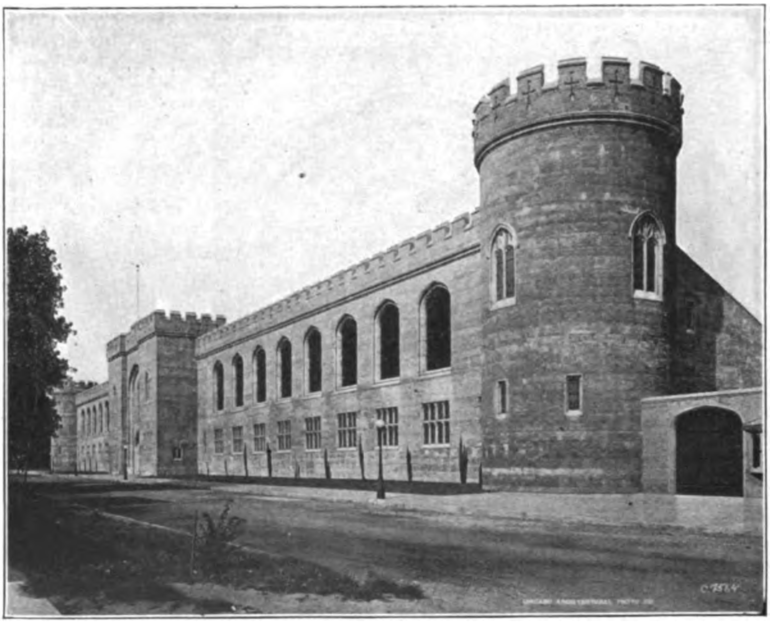
The Grand Stand, Athletic Field, and Bartlett Gymnasium cover the entire block from Ellis Avenue on the West, 802 ft. 9 in., to Lexington Avenue on the East, and from 56th Street South, 597 ft. 5½ in., to 57th Street. The Grand Stand is built on the Ellis Avenue side, and is 456 ft. long and 99 ft. 4 in. wide. These dimensions do not include the two circular towers on the ends or the main entrance bay. The appropriation for the Stand and Fence was $200,000, which has not been exceeded.

There are 34 tiers of seats, with a seating capacity of 8,800, built on an inclined slab. These tiers vary from 28 in. wide and 12½ in. high at the bottom of the Stand to 26 in. wide and 14½ in. high at the top of the Stand. These dimensions were varied so that all spectators might have an unobstructed view of the whole field at all times. A plank is fastened to the slab on the edge of the tier and forms the seat, while the space back of the plank forms the aisle for the tier above. The promenade, just back of and on the level with the highest tier, is 42 ft. 4 in. above the ground floor.



Main Entrance to the Grand Stand.

The main entrance is in the center of the Stand. On either side of the entrance, there are large stairways which go up to the promenade. There is also a stairway in either end which is continued to the promenade through the towers. Between the end stairs and the center stairs there is a stairway on either side between the first and second floors. The second floor is 21 ft. above the ground floor, is 40 ft. wide, and extends the entire length of the Stand. There are short stairways every 36 ft. leading from the second floor to the upper tiers of seats. This floor serves to equalize the crowds on the stairways and also as a shelter. All stairways are wide and easy of ascent, and landings are provided at short intervals. There is a wide corridor on the ground floor through the center connecting the entrances at either end of the Stand. All stairways start from this corridor. On either side of it are hand-ball courts, racquet courts, offices, team rooms, toilets, etc. On the west side of the corridor there are short stairways every 36 ft., leading to the lower tiers of seats.

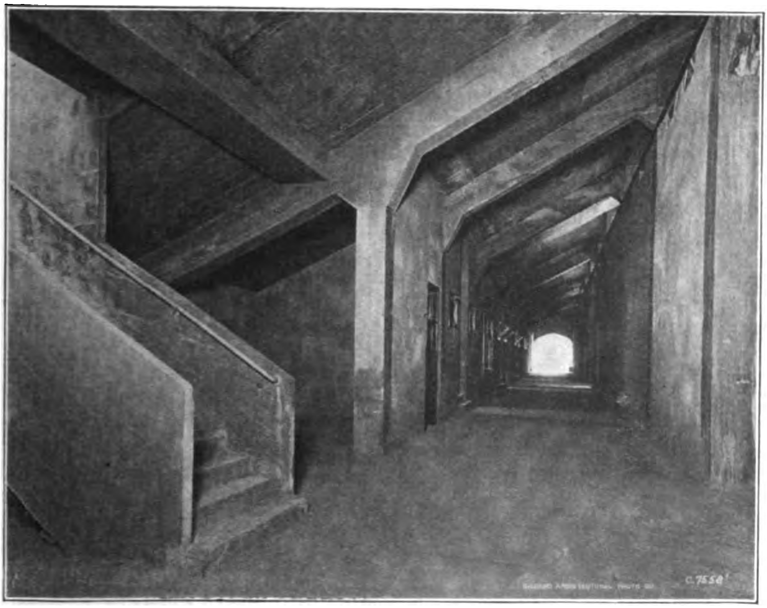


The Front of the Grand Stand and Corner Tower.

All floors, walls, beams, slabs, girders and columns are of reinforced concrete.

The construction of the Stand proper consists of triangular beams (formed by the tiers of seats) reinforced in proportion to the perpendicular depth of the beam. A 4 in. inclined slab, parallel to the slope of the seats, is the base. The tiers are poured at the same time as this slab and these form the beams mentioned above. The typical span for these beams is 18 ft. 2 in., but the three center spans are 26 ft. 9 in. For these three panels the slab is 7 in. deep. These triangular beams were figured as continuous.

All rods are straight; these are lapped 2 ft. and wired together over the girders, in order that there shall be no weak place for an expansion crack. The negative moment is provided for by placing short bars in the top of the slabs over the supports. These bars extend to the quarter point of the span on either side of the girder and are of the same section as the main reinforcing rods.



Under the Grand Stand.

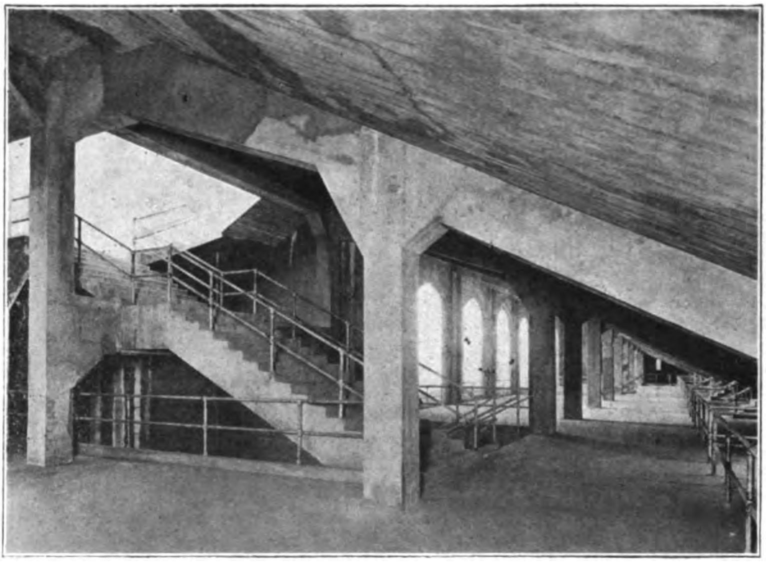
At the top edge of each tier a ⅜ in. rod runs the entire length of the Stand and is wired to the top reinforcement over all supports. Three-eighths inch square rods 18 in. c.c. were placed at right angles to the main reinforcing in the slabs.

The inclined girders supporting the above beams were figured in the usual way. The two highest girders span 20 ft. 8 in. each, the next two 15 ft. 0 in., and the lowest one 14 ft. 1 in.

The stairways in general are built upon concrete slabs, but in several instances where the span is too large, they are carried on inclined beams.

All walls are figured as beams, and loads are transmitted to wall columns. Vertical reinforcement is also provided in all walls and some additional horizontal rods are inserted to prevent temperature cracks. All reinforcing in walls is lapped and wired and all laps staggered, so as to eliminate any weak places in the reinforcement. The exterior walls are 12 in. thick.

In order to get the desired finish for the exterior walls, the inside form was carried up and the supports for the outer forms were put in place. Then the finished shiplap for the outer forms was nailed in place for about 15 in. in height and a sheet of metal placed 2 in. back of it. The space between the metal plate and the outer form was filled with the wall finish and well tamped; then the space between the plate and the inside form was filled with concrete, after which the plate was pulled up and the concrete tamped. After the section of wall being poured was up to an even level, the outer form was built 15 in. higher and the process repeated. The exterior finish consisted of one and one-half parts cement, four and one-half parts limestone screenings (passing a ½ in. screen and retained on a ¼ in. screen), and one-half part sand. The mixture used was of medium consistency. The finish was backed up with a 1-2-4 limestone concrete. The wall columns are 18 in. by 20 in., typical columns 18 in. square, and reinforced according to the load, though a minimum of eight ¾ in. round bars were used, or 1.6% of the effective area. Spiral hooping was used in all columns. This was of ⅜ in. round rods, with a 3 in. pitch.

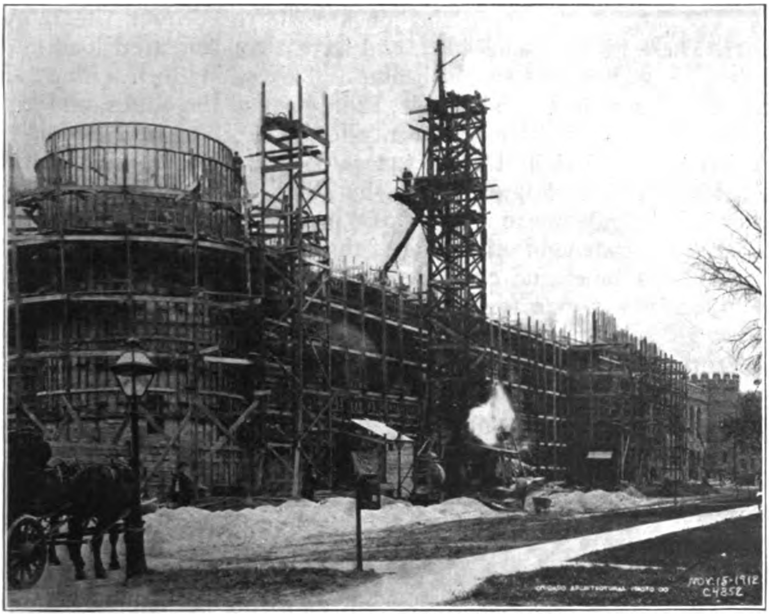


Stairways and Corridor under the Grand Stand.

All girders framing into columns were provided with knee braces, each knee brace being reinforced.

The second floor slab was figured as a two-way slab, having 18 ft. by 20 ft. panels and a slab 6 in. thick. This method required beams in both directions, serving as a stiffener for the structure. These beams were all braced with reinforced knee braces.

All mouldings, sills, mullions, string courses, copings, tracery, transom bars, etc., are of cast cement, made of one part white cement and two parts limestone screenings. Openings were blocked out in pouring walls for this work.



Form Work and Elevating Tower for Concrete Work.

The same finish was used for the wall as for the Grand Stand. The wall is an 8 in. slab, reinforced both ways, carried on columns, and built in bays averaging 15 ft. Each bay has two large panels recessed 1½ in. The columns are flush with the slab on the inside of the fence and form a buttress on the outside. Each buttress has a cast cement cap.

The bottom of the racquet-court floor construction is 10 ft. 5½ in. below the first floor line and just below the ground water line. A special effort was made to have a dry floor and walls. A 12 in. slab reinforced with ¾ in. square bars both ways in the top of the slab was laid on the soil and sloped to a sump in one corner. On this was laid a layer of 4 in. hard-burned hollow partition tile, laid flat so as to drain to the sump. Tarred paper was laid on the tile and a slab varying from 4 to 7 in. was poured. This slab was also reinforced with ½ in. square bars 12 in. c.c. both ways in the top of the slab. So far, no water has drained into the sump and the floor is perfectly dry.

There are no expansion joints in the building. Every effort was made to place all steel so as to have no weak places. All rods are fully lapped and wired and all intersections wired. All walls, curbs, etc., are reinforced to prevent expansion cracks, and to date none have appeared. The only lines or seams visible are where the pouring of the concrete was discontinued for a day or so.

The largest girders in the job are the three over the racquet court. These girders span 40 ft. and have a concentrated load in the center. They are figured as tee beams and are 42 in. deep with a 28 in. web. The flange is 9 ft. 6 in. wide, 12 in. deep at the edges, and 18 in. deep at the web. There are twenty-four 1¼ in. square bars in the tension side, and eight 1¼ in. square bars in the compression side.

The seat boards are of 2 in. by 10 in. Oregon Fir, supported every 4 ft. by galvanized sections of 4 in. I beams, 7½ in. long. These I beams are fastened to the edge of the tier by 4 in. expansion bolts.

A 1-2-4 limestone concrete was used throughout the job; all floors, stairways, passageways and tiers for seats were finished off with a 1-2 sand mortar applied as quickly as possible. For all work underground, hydrated lime was used as a waterproofing medium, the proportions being 10% of lime by weight of cement.

High elastic limit, square, deformed bars were used throughout except for stirrups and column hooping.

All beams, slabs, and columns were figured according to Chicago ordinances.

DISCUSSION.

J. H. Prior, M. W. S. E. (Chairman): I was particularly interested in Mr. Hodgdon's statement as to the permanency of this structure at the University of Chicago. It makes me think that anything that appeals to primitive instincts is liable to have long life.

W. C. Armstrong, M. W. S. E.: I would like a little information about the fitting of those steps with seats. I understand they were poured at the same time as the slab underneath. How were the forms for the steps made and supported when the slab was constructed underneath? Am I right in the statement that they were all poured at the same time?

Mr. Hodgdon: Yes, you are correct in your understanding as to the pouring. When the riser for the steps was placed, we set pegs down into the slab as that was poured to keep the tread from moving. It was a difficult thing to do, and the people who built the Harvard Stadium said it could not be done.

Mr. Armstrong: Those supports go down through the slab, I suppose, and are removed afterwards.

Mr. Hodgdon: Yes, after the concrete had set about a day, the supports were removed, and the holes filled.

L. J. Mensch: I do not think it good practice to wire the rods together.

J. F. Brown: How long were the forms left on the concrete before stripping them off, and how long a time elapsed after the stripping before the edifice was used?

Mr. Hodgdon: I do not remember how long the forms were on the concrete before stripping, but three-fifths, or perhaps four-fifths of the Stand was used for the football game just before Thanksgiving. The last photograph was taken December 6th. The Stand was used really while it was under construction.

Wirt F. Smith, ASSOC. W. S. E.: Do the feet of the spectators rest on the concrete or on a separate plank? I had the pleasure of witnessing a very enjoyable football game in the Harvard Stadium, but my feet were on the concrete and the discomfort experienced made me almost forget to enjoy the game.

Mr. Hodgdon: Well, your feet would be on the cold concrete here, but you had to sit on the cold concrete at Harvard.

Mr. Smith: No, there were loose planks on the concrete.

Ernest McCullough, M. W. S. E.: I was interested, in the work described tonight, to see how great pains were taken to buck nature in regard to the effects of temperature upon a structure of that kind. The author does not seem to be very enthusiastic over the lasting qualities of concrete, because of the effects of temperature upon concrete Stadia previously erected by other institutions. I think he has every reason to be dubious about the appearance of this structure 15 or 20 years from now, and perhaps sooner.

We do not know as much about the effects of temperature on concrete as we should—we are learning all the time—but we do know there is practically an irresistible force exerted by temperature upon massive structures, and it is only good, hard-headed, common sense to give nature a little chance to move around. I believe it is not possible for us to erect a structure of that magnitude and put in enough steel to take care of temperature stresses so it will be free from cracking. The committees on surface treatments of concrete in various organizations have reported that all concrete will crack. We know that. The only reason finely finished concrete seems to crack most is that the surface is ideal to indicate cracks.

Concrete, which is coarser in texture, probably cracks just as much as any, but it has a surface not so well fitted to show it.

On the structure recently erected for the University of Chicago, I believe the architects and engineers in charge were very greatly in fault when they attempted to overcome the effects of temperature upon the massive structure by supplying an immense amount of steel. They could just as easily have provided some kind of unit construction and allowed the units some play.

A large number of buildings have been erected all over the country with monolithic roofs, but those roofs are gradually getting into bad condition. Numbers of men who advocate monolithic roofs advise some sort of composition covering, and a great many are putting up roofs with small slabs on top, simply because of the expansion and contraction, to guard against which they do not seem to be able to supply enough steel.

In sidewalks there has been controversy over the effects of temperature. When I was building sidewalks, as a superintendent of construction for a concrete company, we would run in half a mile of sidewalks without an expansion joint. They would go perhaps three years without a crack, and then would crack in a night. It may be shrinkage stress rather than expansion stress, but we do know however concrete is made, sooner or later the effect of temperature will be manifested, and enough steel cannot be used to take care of it. If steel is put too near the surface the difficulty is increased, for then cracks appear; moisture gets in to rust the steel and it expands. .

Mr. Prior: The Monadnock building is 600 ft. long and I know of no expansion joints.

Mr. Hodgdon: In regard to expansion cracks, in the Stadium at Syracuse, expansion joints were placed, I think, every 30 ft., and that has cracked wherever it pleased. In the University Stadium we decided to eliminate the expansion joints.

I. F. Stern, M. W. S. E.: I was interested in exactly the same point Mr. McCullough mentioned, regarding the effect of expansion and contraction. In building retaining walls for the track elevation in Chicago, we tried to take care of that matter and keep the walls from cracking. We usually built dovetailed joints every 32 ft. We would build the retaining wall in alternate sections so as to give each section a chance to set before the next section would be built and then have a tar paper joint or some other device for maintaining each section separate from the other. We did not use reinforcement, as these were gravity walls. It has been my experience that even in those cases the concrete will crack intermediately between the 32 ft. joints.

I am inclined to agree with Mr. McCullough in thinking they are liable to have considerable trouble with the University of Chicago wall, because in practically all walls of any length, when you get over 100 ft. with expansion joints and with reinforcing joints, cracking occurs. I think it will be very interesting to look at that wall about ten years from now and find out whether the designer of that time will point to it as a horrible example of what was done and what to avoid.

Mr. Prior: In the matter of expansion, I notice that Mr. Stern selected an example where the expansion would take place in a straight line in one direction. It is easy to predict, on a longitudinal wall, that a joint substantially at right angles to the face would take up most of the expansion. In a complicated structure, however, in which the place to put a joint would be at every important point of stress caused by temperature, in a structure like that just described by Mr. Hodgdon, the proper location of expansion joints is a difficult matter.

PROCEEDINGS OF THE SOCIETY

Minutes of the Meetings.

Extra Meeting, December 29, 1913.

An extra meeting of the Society (No. 843), a joint meeting of the Electrical Section, W. S. E. and the Chicago Section, A. I. E. E., was held Monday evening, December 29, 1913. The meeting was called to order at 8:30 p. m., by Mr. R. F. Schuchardt, chairman, with about 40 members and guests in attendance. The minutes of the previous meeting were approved without reading as they had been printed in the Journal.

The following nominations for officers of the Electrical Section for 1914 were made:

Chairman	F. J. Postel
Vice Chairman	H. M. Wheeler
Member Executive Committee	E. W. Allen

Petition signed by J. R. Cravath,
R. F. Schuchardt,
Wm. B. Jackson.

Mr. H. W. Young was introduced, who presented his paper, "Moderate Capacity Outdoor High Tension Sub-Stations." Many lantern slide views were shown in explanation of the paper. Discussion followed from O. Wingard, E. W. Allen, L. L. Perry, Wm. B. Jackson, H. B. Gear, J. R. Cravath, L. N. Boisen, F. C. Van Etten, M. G. Lloyd, and D. W. Roper, with replies and explanations from Mr. Young.

Meeting adjourned at 9:50 p. m.

Annual Meeting, January 7, 1914.

The Forty-fourth Annual Meeting of the Society (No. 844) was held Wednesday evening, January 7, 1914, in the Red Room, Hotel La Salle, Chicago. The meeting was the most largely attended, and was a very successful meeting. The annual dinner was served about 7 p. m., with 264 in attendance, including many guests. At the Speakers' Table were seated the toastmaster, Dr. Edwin H. Lewis, President Albert Reichmann and President-elect E. H. Lee, the speakers for the evening; Dean Mortimer E. Cooley, of Ann Arbor, Mich., and Mr. S. E. Kiser, of Chicago; also, Past Presidents Andrews Allen, J. W. Alvord and O. P. Chamberlain. After the dinner had been eaten, the President called on the Secretary for an abstract of his annual report. This will be found elsewhere in this Journal. The President then made his address in which he stated the results of the recent election of officers of the Society. Mr. Reichmann then introduced Mr. E. H. Lee, as President of the Society for the current year. Mr. Lee made an appropriate response and introduced Dr. E. H. Lewis, of Lewis Institute, as toastmaster. Dean Mortimer E. Cooley, the principal speaker for the evening, addressed the meeting on "Factors Determining a Reasonable Charge for Public Utility Service." Mr. S. E. Kiser followed with a witty speech which was called "Alternating Currents."

During the evening a telegram was received by the Secretary from Past President Bion J. Arnold, at Denver, Colo., tendering his congratulations and best wishes to President E. H. Lee and the Board of Direction, and regretting his inability to be present.

The meeting adjourned about 11 p. m.

Extra Meeting, January 8, 1914.

An extra meeting (No. 845), a smoker, was held Thursday evening in the Society rooms, which was well attended. President Lee made some interesting remarks about the Society, its function, and the necessity of more sociability and good fellowship among the members. He told some good stories and called on those present to do the same. Music was supplied from time to time by an Edison graphophone. Refreshments were served and all present seemed to have enjoyed themselves.

Meeting adjourned about 11 p. m.

Extra Meeting, January 12, 1914.

An extra meeting (No. 846) was held Monday evening, January 12, 1914. This was the annual meeting of the Bridge and Structural Section, and was called to order at 8:20 p. m. by President Lee. The Secretary announced that an election was in order for members of the Executive Committee of the Section, and that at the last preceding meeting, held December 8, 1913, nominations had been made for Chairman, Vice-Chairman and members of the Executive Committee. Ballots were cast and the results of the canvass of these showed that J. H. Prior was elected Chairman, J. W. Musham was elected Vice-Chairman, and that E. N. Layfield and H. C. Lothholz were elected members of the Executive Committee. The retiring chairman, I. F. Stern, is also a member of this committee.

Mr. W. M. Wilson, M. W. S. E., was then introduced, who read his paper (with lantern slide illustrations) on "Movable Bridges." As the hour was rather late when this was concluded, Mr. F. G. Vent offered a motion that discussion of the paper be postponed until some subsequent meeting. The motion was carried.

Meeting adjourned about 10:45 p. m.

Extra Meeting, January 19, 1914.

An extra meeting (No. 847), being the annual meeting of the Hydraulic, Sanitary and Municipal Section, was held Monday evening, January 19, 1914. The meeting was called to order by Chairman Langdon Pearse at 8:15 p. m., with about 60 members and guests in attendance.

The chairman announced that nominations for members of the Executive Committee for 1914, were in order. Nominations were made as follows:

Chairman	W. D. Gerber
Vice-Chairman	G. C. D. Lenth
Members of Executive Committee	W. W. DeBerard and Douglas Graham

These were duly elected with Langdon Pearse as a hold-over member of the committee. Mr. J. W. Alvord was then introduced, who addressed the meeting on "The Engineering Lessons from the Ohio Floods." This was illustrated by many lantern slide views.

Discussion followed from Messrs. Langdon Pearse, F. E. Davidson, G. C. D. Lenth, J. W. Alvord, B. E. Grant, W. W. DeBerard, F. J. Postal, and others.

Meeting adjourned at 10:15 p. m.

Extra Meeting, January 26, 1914.

An extra meeting of the Society (No. 848), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Monday evening, January 26, 1914. The meeting was called to order at 8:20 p. m., R. F. Schuchardt presiding, and with a very large attendance, estimated at nearly 300. The Chairman announced that the election of three members of the Executive Committee was in order and that nominations for these had been made at the previous meeting. The Secretary read their names as follows:

F. J. Postel	Chairman
H. M. Wheeler	Vice-Chairman
E. W. Allen	Member for 3 years

The Secretary, by vote, was requested to cast the ballot for these officers. The hold-over members of this Executive Committee are G. T. Seely, for 1 year, and P. B. Woodworth, for 2 years.

President E. H. Lee was introduced, who made a short address. Mr. B. J. Arnold was then introduced, who addressed the meeting on "City Transportation, Subways and Railroad Terminals," with lantern slide illustrations. There was some discussion and some questions were asked of Mr. Arnold by Messrs. Fowler, Lyman, Davidson, Bement, Lake, Brooks, Lenth, Vent, and others.

Meeting adjourned at 10:55 p. m., after a vote of thanks had been tendered Mr. Arnold.

J. H. WARDER,
Secretary.

ANNUAL REPORTS.

SECRETARY'S REPORT.

Chicago, January 7, 1914.

To the Board of Direction, Western Society of Engineers, Chicago:

Gentlemen:—Of the affairs of the Society for the year 1913 I beg to report that they have been fairly satisfactory, with a growth in membership greater than in either of the preceding two years.

New members to the number of 116 were added to the Society during 1913, but there were some resignations, (6) deaths, and others were dropped for non-payment of dues, which lessened the actual increase of membership to 85.

The membership of the Society, December 31, 1913, was as follows:

Honorary Members	3
Members	781
Associate Members	238
Junior Members	153
Affiliated Members	47
Student Members	26
Total membership	1,248

The following have been removed from among us by death:

J. W. Crissey, admitted March 17, 1896; died March 7, 1913.
M. H. Dance, admitted August 5, 1908; died December 12, 1912.
James W. Johnson, admitted January 19, 1912; died January 14, 1913.
Rudolph Link, admitted November 5, 1895; died December 18, 1913.
Oscar Sanne, admitted March 1, 1898; died April 4, 1913.
R. B. Seymour, admitted December 30, 1890; died January 14, 1913.

Meetings of the Society or of the Sections have been held generally on Monday evenings, except in July and August, and these amounted to 38, as follows:

Wednesday, January 8, 1913 (No. 806), the annual meeting and dinner at the Hotel Sherman, with addresses from the retiring president, Mr. W. C. Armstrong, and from the incoming president, Mr. Albert Reichmann; also from Judge C. S. Cutting, Dr. Emory R. Johnson and Dr. C. B. Strouse.

Thursday, January 9 (No. 807), a smoker in the Society rooms with a diversified entertainment and refreshments.

Monday, January 13 (No. 808), a meeting of the Bridge and Structural Section. Mr. A. C. Janni, of St. Louis, presented his paper, "Design of an Arch System by the Method of the Ellipse of Elasticity."

Monday, January 20 (No. 809), a meeting of the Hydraulic Sanitary and Municipal Section. Mr. Edward Hines, of Detroit, Mich., addressed the meeting on "Concrete Roads."

Monday, January 27 (No. 810), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E. Mr. B. G. Lamme of Pittsburg addressed the meeting on "The Desirability of Revising the Rating and Methods of Testing Electrical Apparatus."

Monday, February 3 (No. 811), regular meeting. Mr. Jarvis Hunt presented "A Proposed Central Passenger and Freight Terminal for Chicago Railroads."

Monday, February 10 (No. 812), a meeting of the Bridge and Structural

Section. The paper by Mr. Edward Godfrey on "Railroad Bridge Design in Europe and America Compared" was read by the Secretary.

Monday, February 17 (No. 813), an extra meeting. Mr. Roderick Peattie read his paper on "The Topography of the Bed Rock Under Chicago."

Monday, February 24 (No. 814), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E. Mr. L. B. Andrus presented his paper on "The Application of Synchronous Motors to a Water Power Transmission System for the Betterment of Service Standards."

Monday, March 3 (No. 815), regular meeting. Mr. Paul Hansen addressed the Society on "Improvements of Waterworks Management." There was also a Topical Discussion on "The Legal Status of the Engineer."

Monday, March 10 (No. 816), a meeting of the Bridge and Structural Section. Prof. F. O. Dufour presented "Some Experiments on Highway Bridges Under Moving Loads."

Monday, March 17 (No. 817), a social meeting and a smoker. Mr. W. R. Patterson showed by lantern slide views "The Present Condition of Work on the Panama Canal."

Monday, March 24 (No. 818), a joint meeting of the Electrical Section, W. S. E., and Chicago Section, A. I. E. E. Mr. Halford Ericson, of Madison, Wisconsin, addressed the meeting on "The Regulation and Enforcement of Public Utility Laws."

Monday, March 31 (No. 819), a social meeting and "smoker." Prof. R. D. Salisbury, University of Chicago, gave an illustrated lecture on Patagonia.

Monday, April 14 (No. 820), a meeting of the Bridge and Structural Section. Prof. O. H. Basquin presented his paper on "Columns" for further discussion.

Monday, April 21 (No. 821), a meeting of the Hydraulic Sanitary and Municipal Section. Messrs. Geo. L. Thon and L. R. Howson presented their paper on "The Safe Yield of a Water Shed"; and Mr. S. A. Greeley read his paper, "A Brief Discussion of Rainfall and Its Runoff Into Sewers."

Monday, April 28 (No. 822), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E. Mr. Ralph D. Mershon, President, A. I. E. E., addressed the meeting on "The Value of Joint Meetings"; also on "The Necessity of Reorganization of the U. S. Patent Office and of Correcting the Present Practice."

Monday, May 5 (No. 823), regular meeting. Mr. W. H. Radcliffe read his paper on "The Erection of the Municipal Bridge at St. Louis."

Monday, May 12 (No. 824), extra meeting. Mr. Geo. S. Rice read his paper, "A Suggested Method of Preventing Rock Slides."

Monday, May 19 (No. 825), a meeting of the Hydraulic, Sanitary and Municipal Section. Mr. John Ericson, City Engineer, read his paper on "The Chicago Water Works."

Monday, May 26 (No. 826), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E. A paper by Mr. Leo Dolkart on "Cost Systems in Electrical Contracting" was read by the Secretary.

Monday, June 2 (No. 827), regular meeting. Mr. Henry Kreisinger presented a paper by himself and Mr. W. T. Ray on "The Adaptation of Boiler Furnaces to Available Coals."

Monday, June 9 (No. 828), a meeting of the Bridge and Structural Section. Mr. W. T. Curtis presented his paper, "Doubling the Load Capacity of an Old Iron Viaduct."

Monday, June 16 (No. 829), extra meeting. Messrs. C. W. Boynton and J. H. Libberton presented their paper, "Decorative Possibilities of Concrete."

Monday, June 23 (No. 830), a social meeting and Ladies' Night. Mr. Wm. H. Shuey gave an illustrated lecture, "An Amateur Photographer's Story of a Cruise Around the World."

Monday, September 8 (No. 831), regular meeting. Mr. O. P. Chamberlain presented by abstracts sundry papers and reports on "Subways for Chicago."

Monday, September 15 (No. 832), a social meeting. Mr. Charles Truax gave an illustrated lecture on "The Yellowstone National Park."

Monday, October 6 (No. 833), regular meeting. A paper by Mr. T. V. Salt on "The Manufacture of By-Product Coke" was read by Mr. H. B. Kirkpatrick in the absence of the author.

Monday, October 13 (No. 834), a meeting of the Bridge and Structural Section. Mr. Charles Hodgdon, architect, read his paper on "The Grand Stand of the Athletic Field of the University of Chicago."

Monday, October 20 (No. 835), a meeting of the Hydraulic, Sanitary and Municipal Section. Dr. Edward Bartow and Mr. Paul Hansen presented their joint paper on "Water Purification in Illinois."

Wednesday, October 29 (No. 836), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., held in Fullerton Hall, The Art Institute. Dr. Charles P. Steinmetz presented his paper, "Instability of Electric Circuits."

Monday, November 3 (No. 837), regular meeting. Prof. J. F. Hayford addressed the meeting on "Measuring the Earth."

Monday, November 24 (No. 838), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E. Mr. L. B. Andrus presented his paper, "Testing of Horizontal, Lowhead, Water Turbines at Elkhart, Indiana."

Monday, December 1 (No. 839), regular meeting. Mr. J. W. Pearl presented his paper on "Retaining Walls."

Monday, December 8 (No. 840), a meeting of the Bridge and Structural Section. Prof. Albert Smith presented his paper, "Wind Loads on Buildings with Report of Tests."

Monday, December 15 (No. 841), extra meeting. Mr. Meyer J. Sturm addressed the meeting on "Ventilation."

Wednesday, December 17 (No. 842), Mr. Franklin H. Wentworth, of Boston, addressed the meeting on "A Campaign to Prevent Fire."

Monday, December 29 (No. 843), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E. Mr. H. W. Young presented his paper on "Moderate Capacity, Outdoors, High Tension, Substations."

The JOURNAL OF THE SOCIETY was published monthly during 1913, except during July and August. The ten numbers aggregate 1,026 pages of reading matter exclusive of index and table of contents. Advertisements have also been printed, amounting to about 250 pages for the year.

J. H. WARDER, Sec'y.

LIBRARIAN'S REPORT.

To the Board of Direction, Western Society of Engineers, Chicago.

Gentlemen: The Librarian begs to report for 1913, that there has been a constant growth in the library and in its use by our members and visitors.

The additions to our books amount to 342 volumes. These came by purchase (at a cost price of $72.54), as gifts, and as exchange periodicals bound by the Society.

An important piece of work has been done this past year in classifying and listing a large number of pamphlets of engineering interest, amounting to nearly 1,600 pieces. A card list of these has been prepared, making them available.

In this work a large number of pamphlets were weeded out as unnecessary or a duplication of what can be found elsewhere.

Very respectfully yours,

J. H. WARDER, Librarian.

Financial Statement for Year 1913.

CASH.

Balance in bank, January 1, 1913	$ 481.41	
Petty Cash	75.00	
		$ 556.41
Receipts:		
Members' dues and subscriptions	12,045.60	
Entrance fees	1,354.50	
Subscriptions (non-members)	292.12	
Advertising	2,709.50	
Sales of Journals	129.35	
Interest	883.61	
Rentals	669.50	
Badge pins	107.50	
Miscellaneous	857.16	
		19,048.84
		$19,605.25
Disbursements:		
Salaries	6,451.53	
Journal	3,490.88	
House expense	3,879.24	
General printing	1,072.35	
Stationery, postage and exchange	972.79	
Library	316.21	
Furniture and fixtures	152.72	
Investments	2,069.86	
Miscellaneous	178.25	
		18,583.83
Balance in bank and on hand Dec. 31, 1913		1,021.42
		$19,605.25

OPERATION.

Income:			
Journal:			
Advertising	$3,393.43		
Members' subscriptions	2,288.08		
Subscriptions (non-members)	276.86		
Sales of Journals	129.35		
		$ 6,087.72	
Entrance fees		1,344.50	
Members' dues		10,054.07	
Rentals		669.50	
Interest		694.07	
			$18,849.86
Expense:			
Journal:			
Salaries	$3,301.98		
Printing, engraving, etc	3,451.01		
		6,752.99	
Office salaries		3,014.28	
House expense		3,590.36	
General printing		774.96	
Stationery, postage and exchange		979.64	
Depreciation and insurance		807.88	
			15,920.11
Proft and loss			2,929.75
			$18,849.86

January, 1914

Assets:		
Cash	$ 1,021.42	
Accounts receivable	4,159.44	
Investments in bonds, etc.	13,573.44	
Accrued interest on investments	314.98	
Furniture and fixtures	1,479.99	
Library	8,581.04	
Journals	200.00	
Pins and certificates on hand	61.54	
New quarters	2,961.10	
Premiums, unexpired insurance	299.84	
Liabilities:		
Accounts payable		$ 1,601.20
Chanute medal fund		974.50
Dues and subscriptions prepaid		144.19
Surplus		29,932.90
	$32,652.79	$32,652.79

J. H. Warder, Secretary. C. R. Dart, Treasurer.

REPORT OF THE CHANUTE MEDAL AWARDS.

January 1, 1914.

To The Board of Direction, Western Society of Engineers.

Gentlemen:—Your committee appointed to make recommendations as to the award of the Chanute Medal has been delayed by the fact that the papers presented do not readily fall into the classes of civil, mechanical and electrical engineering, which have been heretofore recognized, but in view of previous rulings of the Board as to the basis upon which these awards are to be made, supplemented by the special instructions given by the Board on request of this committee, the recommendation is made that the medals be awarded as follows:

To Onward Bates for his paper on "Arbitration," which we place in the classification "General Engineering."

To D. W. Mead for his paper on "The Cause of Floods and the Factors that Influence Their Intensity" under the classification of "Civil Engineering."

To W. L. Abbott for his paper on "The Northwestern Station of the Commonwealth Edison Company" under the classification of "Mechanical and Electrical Engineering."

Respectfully submitted,

(Signed) E. N. Layfield,
E. H. Bangs,
C. Kemble Baldwin,
Committee.

REPORT OF THE JUDGES OF ELECTION.

Chicago, January 2, 1914.

The undersigned judges of election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1914, have the honor to report as follows:

Total number of votes cast	480
Number of ballots rejected as irregular	14
Number rejected as not qualified to vote on account of non-payment of dues	6
Total number of ballots counted	460
Number of votes cast for President:	
T. L. Condron	158
Wm. B. Jackson	111
E. H. Lee	187

Number of votes for First Vice-President:	
B. E. Grant	226
E. N. Layfield	206
Number of votes cast for Second Vice-President:	
H. J. Burt	165
Ernest McCullough	174
I. F. Stern	111
Number of votes cast for Third Vice-President:	
G. F. Gebhardt	410
Number of votes cast for Trustee for three years:	
H. S. Baker	247
C. D. Hill	179
Number of votes cast for Treasurer:	
C. R. Dart	423

Respectfully submitted,
(Signed) { Chas. Stewart,
J. H. Heuser,
E. B. Wilson
Judges of Election.

ADDRESS OF RETIRING PRESIDENT ALBERT REICHMANN

Members of the Western Society of Engineers, and Guests:

Last year at this time I was foolish enough to believe that I could become an orator in the course of a year. I soon learned that orators, like poets, are born and not made, and inasmuch as the Secretary could not possibly spare the time to write my address for me, I was obliged to depend upon myself.

You have heard the report of the Secretary. Considering that last year was the unlucky thirteen, and that business generally was not over prosperous, I think that we can feel fairly satisfied with the increase in membership and condition of the Society's finances. I take occasion here to express my deep appreciation to the members of the Board of Direction and the various committees who have so nobly assisted and supported me during my term of office.

I believe our Journal is becoming better each year, due largely to the untiring efforts on the part of our Publication Committee.

It affords me pleasure to announce that the Octave Chanute Medal has been awarded for the three best papers presented during the year 1912, as follows:

Mechanical and Electrical Engineering.

Mr. W. L. Abbott—"The Northwest Station of the Commonwealth Edison Company."

General Engineering.

Mr. Onward Bates—"Arbitration."

Civil Engineering.

Mr. D. W. Mead—"The Cause of Floods and the Factors that Influence Their Intensity."

Some of our members may not know that a committee of members of this Society has been in existence for about ten years, appointed to secure space somewhere in the downtown district of Chicago for the location of a 100-foot Standard of Length, which would be accessible to any and all persons having occasion to make use of it. It is with considerable gratification that I am able to state that during the closing months of the past year the faithful and painstaking work of the committee has been finally crowned with success, and the Standard, properly calibrated, has now been installed complete in the basement of the City Hall building. A history of this Standard of Length will be published in an early issue of the Journal.

Although engineers in general are extremely modest and are most anxious to keep out of the lime-light, nevertheless they seem to receive more recognition each year as time goes on. In the earlier stages of railroad building, the engineer's office was usually found in the attic of an office building, if it had one, or in some other out-of-the-way place. Today it is not uncommon to find the Chief Engineer's office adjacent to that of the Vice-President's or General Manager's office and the engineers of our railway systems are now given the recognition they deserve. We find the same conditions prevailing to a certain extent in our public affairs. The expenditures of our street railways in Chicago are supervised by a Board of Engineers. We have a number of engineers appointed to look after the construction of the proposed subway for the City of Chicago, and we also find an engineer on the Public Utilities Board recently appointed. While engineers were always employed in these various undertakings, they were never given the rcognition they receive today.

Last year, while all the civic organizations about Chicago were very busy making various recommendations to the City Council in reference to the ordinance for building the new Pennsylvania Railway terminal station, some recommending that the City Council select one of their members as an adviser to the City Council, the Western Society of Engineers, through its Board of Direction, recommended that the City Council, before passing the ordinance, secure the advice of some competent expert, with the result that an eminent engineer was selected for that purpose. . Moreover, some of the civic organizations, not having too much confidence in the advice and judgment of one engineer, employed other engineers to check up the expert selected by the City. Thus, the engineers, by assuming a dignified and modest stand, were awarded the prizes on that occasion. I believe that all of these engineers are members of this honorable body.

At our last year's banquet, our retiring President, Mr. Armstrong, made some reference to securing a home of our own. It is gratifying to state that we have, at least in a tentative way, new quarters in prospect. If the same should develop we will have a home very much more in keeping with our requirements and with the dignity of this Society.

As we all know, Chicago is not only the second largest city in the United States, but also of the Western Hemisphere. It is very fortunately situated in almost every respect; has the very best of railroad facilities, fine water transportation, an abundant supply of good water, which means much for the health of the community, and an inexhaustible supply of good coal for manufacturing purposes. It has the very best quality of iron ore almost at its door, as the cost of transporting the same to our city by water is very nominal. In other words, it has the essential materials required in industry.

It is situated in the very heart of the greatest agricultural district of the world, which supplies it with its necessary food products and at the same time affords a good market for its manufactured goods. Its banking facilities have grown wonderfully in the past few years.

Commanding, therefore, one of the most eminent positions in industry and commerce, among the great cities of the world, it requires the services of many of the very ablest engineers. It is our duty to our community to provide this service, to render it faithfully as individuals, and to see that the quality of that service is not only maintained but improved. How can we better secure these results than through cooperation? There are not enough local members of the various national engineering societies to form effective separate local organizations, nor do I think it would be desirable if it were possible, but by joining or in some manner affiliating with the Western Society of Engineers, we could afford to have a very fine library, meeting rooms, etc.

There is but one architectural society, one bar association—why should we be separated into minor organizations when we could accomplish so much more by united action and association? I would, therefore, recommend that we do all we can to bring all the engineers of this community under one roof. (Applause.)

The Constitution provides that the President shall, at the annual meeting, announce the result of the election of officers for the current year. Our recent election has resulted as follows:

President	E. H. Lee
1st Vice-President	B. E. Grant
2nd Vice-President	Ernest McCullough
3rd Vice-President	G. F. Gebhardt
Treasurer	C. R. Dart
Trustee to serve for three years	H. S. Baker

Having thus performed my final duty, it merely remains for me to introduce the new President and turn over to him this gavel and join the great army of "has-beens."

This year we joined in the spirit of the times and had three candidates for the office of President. Unfortunately the other candidates, while they are all residents of Chicago, had never met our president-elect and I believe knew very little about his ability to run, for if they had they could have seen at a glance that it would not take much effort on his part to out-do them in the race.

Gentlemen, I take great pleasure in introducing our President, Mr. E. H. Lee.

ADDRESS OF PRESIDENT-ELECT EDWARD HERVEY LEE.

Gentlemen, brothers and friends: The old proverb hath it "From hearing comes wisdom, from speaking repentance." (Laughter.) As to whether repentance shall be on the part of the speaker or the listener, deponent saith not. (Laughter.)

I address you tonight, gentlemen, with mixed feelings. I have not yet recovered from the surprise occasioned by my election, and the necessity of speaking to you. But I want to take this opportunity to say in this connection that I have experienced one pleasure, a pleasure which was had regardless of the result of this election; namely, that we had three strong men engaged in a friendly contest for this particular office. I regard that as one of the best indications of the life and vitality of this Society. I think as long as we can maintain a friendly rivalry for the offices, we shall progress. Other societies and social organizations have found it necessary to introduce just what we have. I know of at least one important organization in this city where they are now making an effort to introduce just this good thing which we have here in our Society.

Gentlemen, I wish I were eloquent enough to do this occasion justice. As I look on this splendid assemblage of members of this Society, I am inclined to remember the story of the old negro woman in Charleston during the earthquake. She woke up with the bed rocking and the chinking coming down out of the ceiling, and when the logs began to creak, she piled out of bed, rushed out onto the street, dropped on her knees and began to pray. Her prayer ran something like this: "Oh, Lawd, come down hyah and help us. Come down hyah quick, Lawd, we's havin' a awful time, Lawd. Come down hyah, come down quick, and come yo-self, don't send yo' Son, dis hyah aint no child's play." (Laughter.)

The first meeting of the Society that I ever attended was in a little room on this street, perhaps two blocks north of this building. I presume at that time the membership did not exceed one hundred; the average attendance certainly did not exceed ten or fifteen per cent of that number. I look around tonight and see a few of the old, familiar faces. We all know them and we all love them.

Now, we have listened to the table address of our former President, and I feel sure that the other speakers whom we have on the program tonight will so delight us that I am disposed to cut these remarks something short of an hour. (Laughter.) But this is the first occasion that I have ever had an opportunity to address an audience of this distinguished character from the speakers' table and I wish to take advantage of that fact. (Laughter.) Having been successful in this election, I am willing to do, as my friend an Irishman one time was willing to do. He was navigating down the street (laughter) pretty well lit up (laughter), and he came to what he regarded as the last place for another libation. He pushed through the outer door to the vestibule, and saw nobody there. He continued to a second door. As a matter of fact he had come into a revival meeting, and just as he opened the door the revivalist had come to the peroration of his address, which ran something as follows, the subject matter being the judgment day and the division of the sheep from the goats: "In that last dreadful day, is there any one in this audience who is willing to be a goat? Is there any one here who would be willing to be a goat?" The Irishman stood balancing in the door, and he roared, "Well, I'll be the goat to keep the game going." (Laughter and applause.)

Now, gentlemen, I feel that I should fail in my duty without some word as to our noble profession. In the old days the military engineer fashioned the engines and constructed the fortifications—the military engineer unknown and unsung—which were the basis for the later success which made his military leader famous. Today the engineer, the lineal descendant of the old military engineer, the civil engineer, be he electrical, hydraulic, bridge engineer, or what not, by his activities for the most part unheralded and unknown, is laying, and during the last fifty years has laid, the foundation for wealth and prosperity, the basis for the material civilization that we see today. (Applause.)

Gentlemen, I feel that with this friendly audience (laughter)—

A Voice: You're right.

President Lee (continuing): I know I am right. I feel that with this friendly audience, I shall not be accused of boasting when I say that this noble profession, the greatest profession in the country, is without equal. For what of the law? that great profession which is crowded with the brilliant intellects of the country, whose wit and eloquence delight and sway thousands and tens of thousands. (Applause.) Is it too much to point out that this noble profession may be something like the crab, which goes forward backward? (Laughter.)

Now gentlemen, by that remark I do not wish to be understood as saying that the profession of the law is retrograding, but simply that in looking backward to precedent with the face to the rear it is difficult to advance. And what, but our present material development, the work of the engineer, makes possible the fat fees and emoluments for which our friends the lawyers strive?

What of the great profession of medicine? It is entirely beyond my power to describe its wonderful attainments. The work of Colonel Gorgas, in creating sanitary conditions in Havana and Panama (applause)—those pest holes of the tropics—has rendered them as safe and habitable as any city of the Temperate Zone. His work applied the discoveries of his colleague of the Army, discoveries which developed methods of preventing malaria and the other fevers. What of the wonderful discovery of vaccination for typhoid fever which has revolutionized practice, and which has so changed conditions that while thousands died, or came back invalided from the Spanish-American War, during the last two years our troops have been along the Texas border with scarcely a man suffering from this dreadful scourge. What of the wonderful achievements of those two eminent Americans, Drs. Strong and Teague, who went into Manchuria, and at the greatest personal risk discovered the means of preventing the pneumonic plague, another manifestation of the bubonic plague? Words fail to characterize these wonderful discoveries.

And yet, gentlemen, am I beyond the bounds of reason when I claim that the achievements of the engineer in transportation, in methods of communication, in the civilization which we now have, have rendered these great medical discoveries possible? (Applause.)

We have another profession, gentlemen, a great profession, friends of ours, the architects. They have produced many a stately building; and as long as the architect is an engineer or has an engineer back of and supporting him (laughter) he is pretty apt to do creditable work. (Laughter and applause.)

It is an honorable profession. And, gentlemen, I think that the engineers should take a leaf from the note-book of this notable profession. I venture the suggestion, brought to mind by recent illustrations in our allied profession, that the backward and modest engineer should assume some of his prerogatives and rights, should cultivate publicity, should adopt, forsooth, the little Jack Horner attitude, and when he pulls out a plum should advertise the fact that he is a pretty good boy. (Laughter.)

Gentlemen, our profession is based upon solid work, unassuming work. We do not make much money. We have no time to make money. We are not ordinarily very successful as publicity agents. We haven't time to chase the bubble reputation. I am one of those, however, who believe that we are, without being greatly endowed with this world's goods, the happy men in the professional world today, as defined by Emerson when he says, "I look on that man as happy, who, when there is a question of success, looks into his work for reply, not into markets and not into opinion."

Gentlemen, we have with us tonight an educator who is doubtless well known to a great many of our members. He has been connected with one of our leading engineering schools for a great many years. He is to act as our toastmaster, and it affords me great pleasure to introduce Dr. Edwin H. Lewis, Dean of Lewis Institute. (Applause.)

Toastmaster Lewis: Mr. President and gentlemen: For some strange reason which I do not understand, I see—although we have had some reference to Michigan, and are still to have more of Michigan tonight—I see before me certain quantities of Lake Michigan water which are not yet consumed. Now, gentlemen, this is the 85th birthday of the President Emeritus of Michigan, Dr. Angell, and I am going to propose the health of Dr. Angell, and ask you to stand and drink it in Lake Michigan water.

(Standing, the assembly drank the toast to Dr. Angell.)

Gentlemen, I have also observed, although there have been references here to prayer, both by the President and others, that you had no grace, either before or after eating. In this morning's *Record-Herald*, scanning the words of a favorite author of mine, Mr. Samuel E. Kiser (laughter), I read about a boy who wanted to grow up, because when he got grown up he would not have to say any prayers. (Laughter.) Now, why you have not had grace before or after, I don't know. I should hate to think that the prolonged study of mechanics had plunged you into such a radically mechanistic view of the universe that it had ruled out God. Perhaps you feel, like Charles Lamb, that the only proper dinner to be thankful for is one of bread and herbs, because it is simple and refined. Or, finally it may be that you regard prayer as not a public utility but as a sort of private utility. (Laughter and applause.)

Now, that fits my case exactly. This dinner has been of the greatest private utility to me. I am very grateful for it, because, gentlemen, as I have sat here among these alarming specialists, it has protected me to some extent from such questions as "What do think of the effect of water on the underpinning of the carbide works at the Soo (laughter)?" and "Do you think one wire or three wires best to use in block signaling?" When they asked me such questions I have kept my mouth so full that distinct utterance was impossible.

The entertainment committee of this Society has nerve; it has the nerve to go and get here two gentlemen who are so eminently different and differently eminent (laughter), that they could not find anybody to introduce them (laughter). They made a drag-net search of the entire city and state. There was one man who had served in the President's Cabinet who thought that under the circumstances he might be able to introduce a part of the first speaker (laughter), but when he thought of the rest of the first speaker, and all of the second speaker, he decided that he had to go to New York to sue somebody at law. (Laughter.) They tried other people; they tried Governor Dunne, I think—I am not quite certain about this, but as I remember it, he said he would be glad to come, but that Mr. Quan had stolen his pass. (Laughter and applause.) They asked Senator J. Hamilton Lewis, and he said that he was all right when it came to introducing bills or fashions or anything like that (laughter), but that when it came to introducing kings and kaisers, he was not in the same class with another Colonel who was lost down on the Amazon. (Laughter and applause.) I thought that was in very poor taste, to make a joke on Mr. Kiser's name. While an old piece of cheese, you know, will help settle a dinner, sometimes an old joke will have the opposite effect. (Laughter.)

Well, under the circumstances, when they appealed to me, I said, "It is all right." I said, "You will have a couple of presidents there and they will both want to make long, eloquent speeches, and that will take time. After that I will introduce the speakers, but it will take time; it is not a matter of a moment to introduce two such men. I said, "I will come and introduce them, and work at the thing conscientiously for the rest of the evening, and they can come some other time and make their speeches." (Laughter.)

Now, gentlemen, it is a serious thing when two brothers—I don't mean these two brothers, but I am reminded that one of the speakers of the evening has a brother after the flesh who was formerly a president of this Society—it is an awful thing when two brothers from a little town called Canandaigua, New York, try to monopolize all the exact information there is in the country (laughter), about waterways and river improvements and water works and floods and telegraphs and telephones and railways and express companies and plank roads (laughter); and it is still more awful when they so nearly succeed in getting away with it (laughter). One then wishes, when he gets a chance, to get a word in edgewise about the public and public utility corporations. We are the public, and he has the monopoly of the information. A monopoly is like a baby; everybody thinks it is a nuisance until you have one of your own (laughter and applause).

Now gentlemen, when a mere coolie on a railroad becomes the chief appraiser of the railroad, how are you going to appraise the appraiser, or put a limit to what may happen in a democracy? (Applause.) Now, I don't know very much about Dean Cooley, except that he is a famous person. But I asked a competent expert about how much property belonging to utility corporations he thought this man had valued. He said, "About a billion and a half, I guess." Now, I said I thought that was too much. I said, "Look at Mr. J. P. Morgan, deceased. So long as he went into values up to the extent of a billion—that is, an American billion, not an English billion—he got along all right, but when he went beyond that he got his directorates interlocked, the same as a Bull Moose gets his horns interlocked (laughter), and his son has already resigned from 27 of these interlocking directorates and is likely to keep on resigning for the rest of his natural life." (Laughter and applause.) Well, now, I can understand how a first class appraiser will run all the way up to a billion dollars and keep his head straight, but after that I should think he would get his appraisals interlocked. (Laughter and applause.)

I asked the competent expert if he did not think that was so, and he gave me an evasive answer. "Why," he said, "this man is an authority in interlocking. He is chairman of the Board of Block Signalling of the Interstate Commerce Commission." (Laughter.) So then, I gave it up.

But, speaking seriously for a minute, there is one single thought, one sociological generalization, which is suggested to me by the distinction of our first speaker. When Rousseau wrote his *Contrat Social* he precipitated the French Revolution by the doctrine of returning to a primitive society where everything was a matter of free contract. And Herbert Spencer had to say that Rousseau did not know what he was talking about. Primitive society knows nothing whatever of contract, but it is a terrific solidarity, in which the public dictates every single act of the ordinary life of each individual. In that bad old day the public was the whole thing, and for tyranny and unreasonableness it had Nero discounted several ages in advance.

Now, Mr. Spencer contrasted with that primitive condition of things the happy state of the modern Englishman who likes to do what he pleases, and the still happier state of the American, who *does* it. (Laughter.) But we see the limits. There are natural limits of doing what you please, as we all saw when Herbert Spencer left a fund of money to be devoted to keeping the metric system out of England. Now, that would not do. The simple fact of it is that every step in modern liberty has gone hand in hand with standardization, gone hand in hand with new and more exact measurements. And if we have liberty to send a telegram anywhere on the face of the earth, it is because some such man as Lord Kelvin prepared the way for us with his methods of quantitative exactness. So it seems to me that this modern liberty that we are all after—this American individualism which has already been referred to in Emerson—is bound to make in the future for a new and finer subordination of the individual to the social organization.

Society seems to be sometimes like a man who has got arthritis—inflammation of the joints. If there is not perfect suppleness in the social body, some joint is going to get inflamed and stick; then there is going to be trouble. Now, when a man gets inflammation of the joints, of the knee, or the arm, or any such place, you have to decide whether you are going to break that joint or whether you will make a little hole in the joint and pour in some olive oil and two per cent of formalin, and see if you can't limber him up. (Laughter.) The same thing is true, is it not, in the case of public utility organizations sometimes; the question is whether to break or grease them. (Laughter.) You remember the old story of the boy who tried to recite Marco Bozzaris, and got as far as

"Greece, her knee—Greece, her knee—" And somebody said, "Grease her knee and be done with it." (Laughter.)

Well now, gentlemen, before you can decide whether to break the joint or to grease it, you have to know about the joint. You have to have exact quantitative information about the condition of inflammation in that joint, or in that joint stock corporation. (Laughter.) You have to apply the social X-Ray to it. It is being done. And I have the honor to introduce to you the discoverer of what I may call the Cooley Ray, Dean Mortimer E. Cooley. (Dean Cooley's address is printed elsewhere in this issue of the JOURNAL.)

The Toastmaster: It will be somewhat of a wrench for you to shift your attention from this important and impressive paper and the line of thought which it has presented. I do not expect you to do it easily. As I have listened to the extraordinary clarity with which the whole sweep of the field has been expounded, so that even all the joints of the social organism have been X-Rayed and just a little legitimate water found in each (laughter), I have thought that if Dean Cooley desires to appraise two or three billions more, I shall withdraw my objections. (Laughter.)

Now, can we have a song? Can we have, perhaps, "Every Little Movement," as long as we are talking about joints? (Laughter and applause.)

(The song, "Every Little Movement," etc., was rendered.)

The Toastmaster: We are now obliged to turn to a somewhat more technical subject, a branch of electrokinetics (laughter), and here I feel somewhat more at home, because my room at Lewis Institute is on the same floor with the electric laboratory. (Laughter.) I often see the students come in there. And once I saw the professor, or one of them—it was on the train, gentlemen—and I had been cleansing my soul from the stains of the commercial world by reading Mach's Treatise on Mechanics—because I am sure there is nothing in the world in that treatise on mechanics that could possibly be applied to engineering (laughter)—and I looked up from that and saw that this professor was reading; I looked over his shoulder and saw he was reading Browning's poem, "The Ring and the Book." He was married soon after that (laughter), married without impedance or resistance.

Now, the subject of the next speaker is "Alternating Currents." Alternating currents are supposed to be more or less dangerous. And this speaker reminds me of Lord Kelvin, in some ways. (Laughter.) Lord Kelvin, you remember, found a way of eliminating the danger by increasing the tension. Now, the eminent professor that I am about to introduce has a very high tension, so high that they don't allow him to work in a room with electric lights, but only by the light of a tallow candle or his cigar. And they have him insulated above and below, fore and aft, and pro and con, and to and fro. (Laughter.) What they use for insulation I don't know, but I dare say it is bottles. (Laughter.) Of course, he does not look that way, but you never can tell. (Laughter.) Now, this gentleman has not only magnitude, but direction; he is therefore a vector quantity. And he radiates out in a great many directions; therefore he is a sort of polyphase vector quantity. You may not know the polyphase vector quantity, it is something like the monopolar engine that is used in a monohippic college. (Laughter.) This gentleman has a high velocity, and at the same time mere induction from a typewriter has been known to break his circuit into fourteen lines. (Laughter.) His waves are not Herzian, but herzlich. He has a warm heart and many friends. I don't know whether I really dare switch on such a force as this, but I will chance it—and I have great pleasure in introducing Mr. Samuel E. Kiser. (Applause.)

ALTERNATING CURRENTS BY MR. S. E. KISER.

Mr. Toastmaster and Gentlemen: I understood when I was invited to come here that I would be expected to say something funny. Your toastmaster has said all the funny things, and I am going to switch. I am going to discuss public utilities. (Laughter.) There are some interesting and intricate problems concerning public utilities that don't seem to have been touched upon here this evening, and I think they ought to be elucidated. (Laughter.) I am one of the best elucidaters in the business. (Laughter.)

I was much interested in a statement made by your new president a little while ago to the effect that engineers are modest, retiring people. I soon found out from his own statements that they must be. (Laughter.) He began by saying that three strong men had been running for the presidency (laughter and applause); and then he compared engineers with doctors, very much to the discredit of the doctors; and also to lawyers, and left the lawyers gasping for breath (laughter).

I will say, however, that I have noticed this difference between engineers and lawyers. Most lawyers have to rely upon politics in order to get a living, while the engineers don't seem to get into politics very far. There are one or two engineers here in Chicago who are generally in politics to some extent. We hear of them very frequently. They are mixed up with nearly every public utility that comes along, and have more or less to do with controversies that arise at the City Hall. But ordinarily, the engineers seem to get along without politics, which is very interesting and perhaps instructive. Whether it has a bearing upon the problems concerning public utilities or not I shall leave you to judge after I have finished discussing this matter.

I am not going to attempt to cause you to be carried away upon a flood of oratory or a stream of mellifluous and grandiloquent phrases; I will confine myself to a plain statement of facts and fundamental principles, zealously refraining from tautological verbiage and mysterious ramifications within those realms of ultramontanism which might be regarded as terra incognito to people whose forensic perceptions would require an elucidation of the postulate that is to be presented. This being understood (laughter) I may say at the start that there are two things which every man desires to possess, two things which every man wants to have for himself and which no man may be sure of having as his own merely because some other man is deprived of them. There are two things which every man wishes to claim for his very own and which no man may take unto himself from another man. We understand that nearly every man wants to have wealth, but money is not one of the two things to which I have reference, for money may be taken from one man by another. Every man desires to be loved, too, but love is not one of these two precious things which I have in mind, for love, like money, may be transferred (laughter). So it is with public office and with the favor of those in authority. Those things like love and money may be transferred from one man or one group of men to another. But there are two things which every man wishes to have for his own and which no man may take away from another to have in his own keeping—two things that may not be taken away from any man to become the possession of another. One of these two things is long life, and the other is hair on top of the head (laughter and applause).

I am going to start back at the beginning of things, by discussing some of the phases of boy nature. Boys are very interesting. I find them supplying me with a large quantity of my material from day to day. I call to mind one boy in particular who is the possessor of a father (laughter) who belongs to that type which you have all doubtless noticed—one of those fathers who are inclined to look back with a great deal of pleasure to the time when they were boys, a father who in discussing the boy he used to be causes a halo to appear above the head of that sainted child (laughter).

Well, this boy that I have reference to made a sort of study of his father, and at length he came to certain conclusions which I have attempted to embody in some verses that run along about in this way:

I wish that I'd have been here, when my pa was a boy.
There must have been excitement then, when my pa was a boy.
He never, never disobeyed; he beat in every game he played.
Gee, what a record there was made, when my pa was a boy.

Then everything was in its place, when my pa was a boy.
He did things with a smiling face, my pa did, as a boy.
He'd get the coal and chop the wood, and think of every way he could
To always just be sweet and good, my pa did as a boy.

There were a lot of wonders done, when my pa was a boy.
How grandpa must have loved his son, when my pa was a boy.
In school he always took the prize, and he could lick boys twice his size.
I'll bet you folks had bulgin' eyes, when my pa was a boy.

I wish that I had been here then, when my pa was a boy.
There'll never be his like again, pa was the model boy.
And yet I've often heard my ma when she's disgusted, call my pa
The biggest "It" she ever saw. He oughta stayed a boy.

(Laughter and applause.)

This boy's father was the possessor of a keen wit, in his own estimation (laughter). The boy, telling a little story of certain affairs occurring in the home circle, said:

"When I was at the drug store the other day I picked up an almanac and took it home, and last night when pa came in he found the almanac and got to reading in it and commenced to laugh and pretty soon ma asked him what was the matter. He said, 'Here's an awful good joke. I found it in the almanac'; and ma asked him what it was. 'Well,' he said, 'if you'll keep quiet a minute I'll read it to you.' So ma kept quiet a minute, and pa read the joke, and this was the joke: 'Why is the mistake of a doctor not as bad as the mistake of a dentist?' And ma said she'd give it up, so pa read the answer; and the answer was: 'Because the doctor fills six feet and the dentist fills an acher.' (Laughter.) 'Well,' ma said, 'why does he do that?' 'That's the joke,' pa says; can't you see it? 'The doctor fills six feet, and the dentist fills an acher,' you know—six feet of ground, you know. The acre refers to ground, don't you see?' Ma said she knew that. 'But,' she said, 'I don't understand about the six feet part,' and pa said: 'The doctor gives a man the wrong medicine—makes a mistake and gives him the wrong medicine—and fills six feet.' 'Yes,' ma said, 'but I don't see any joke about that. (Laughter.) Why does he fill six feet?' 'Why,' pa said, 'he gives this man the wrong medicine and he dies, and they bury him and fill six feet of ground with him. That makes it come in with the acre.' 'But,' ma said, 'I don't see any joke about that. There's no joke about killing a man, is there?' (Laughter.) 'Oh,' pa said, 'it's merely imaginary. They say he fills six feet, you understand, just to make it come in with the acre. The doctor gives this man the wrong medicine and fills six feet, and the dentist makes a mistake and fills an acre.' 'Yes, but,' ma said, 'what if this man that got the wrong medicine was a short man?' (Laughter.) Pa was beginning to get kind of disgusted along about then and he said. 'Oh, it would be just as good a joke if he only filled four feet—gave the man the wrong medicine and filled four feet. It would be just as good a joke.' 'Yes,' ma said, 'but you said they made a mistake.' 'Of course they made a mistake.' 'Well,' ma said, 'you said the dentist filled an acre, didn't you?' 'Certainly.' 'Well, if he made a mistake he would not fill the acre, would he?' (Laughter and applause.) Then pa read the joke again to see if he had it right and his eyes commenced to get kind of glassy, and pretty soon he tore the almanac into about a dozen pieces and flung it in a corner and says, 'Oh, well, darn it, what's the use trying to bring any sunshine into this family, anyhow?'" (Laughter and applause.)

Your toastmaster has made a very elaborate explanation concerning my habits and profession, but I mistrust that he did it in a tone of levity, with the intention to be more or less sarcastic. Now, as a matter of fact, there are people who are interested in me and in people of my kind (laughter). I once heard of a lady who had developed an interest in a man who was furnishing a daily column for a newspaper. She had been reading him steadily for some time and had become possessed of a desire to see him. She wanted to see what kind of a looking man he might be. And this desire grew upon her until she decided to gratify it.

Finding out where this person was kept (laughter), she went to the newspaper office and inquired for him. The man at the counter down in the business office said he had never heard of him, but he thought if she would ask the elevator man perhaps he might give her some information. She asked the elevator man, and he said that he had heard of this person but he did not know just where he was. He thought if she would get off on the fourth floor and look around there she might find him. She got off at the fourth floor and walked up and down a long hall and looked into the various editorial rooms, and, finally, seeing at a desk, a man who looked like the person she had pictured in her mind, she paused at the door and coughed and made noises calculated to attract his attention (laughter). Finally he turned around, and she said, "I beg your pardon, I am looking for the humorist. I thought you might be the gentleman. Are you the humorist?" "No, I am not," replied. "No, I am not the humorist, I—you see, my house burned down yesterday and I didn't have any insurance. I guess that is what makes me look this way." (Laughter.)

Another lady who had developed an interest—I don't like to be personal about this thing—but really her interest was in me; she had known me when I was a small boy, and when my first book of poems was published she got a copy of it—I don't know how, because my publishers seemed to be trying to keep it secret (laughter). She got this book in some way and went to see my mother about it. My mother lives back in the little town in the East where I was born and raised—or partly raised (laughter)—and the lady who was interested went to see my mother about the matter, and asked: "When did you discover that your son possessed this gift?" My mother thought the matter over and replied: "Why, I think along about when he was 13 or 14 years old. One day he fell out of a tree and struck on his head and we noticed afterwards that he was different from the rest of the children." (Laughter.)

But it was not until some ten years after this that I began to give expression to the beautiful thoughts that arose in me. I was employed in the office of a newspaper in an eastern city at the time. They didn't know then that I was a poet, but one day the managing editor came to me and said: "There is a little space at the end of one of the columns on the editorial page that I would like to fill with a poem. We haven't published any poetry in this paper for quite a while, and I think the public might stand for it (laughter). I wish you would write about twelve lines to fit into that space. Don't write anything that will offend anybody, because—you never can tell—some one might read it (laughter). Just dash off twelve lines. You can do it." "But," I protested, "I am not a poet. I never have written any poetry." "Oh," he urged, "go ahead. This is a good time for you to begin." (Laughter). Well, it was a cold day in the winter and I sat opposite a window looking out into the street, and I could see the snow blowing along there and people were passing along muffled up around their ears, and it looked very disagreeable outside. I tried to argue him out of this poetry notion, but he would not have it, and after a while, seeing how things were outside, I decided that I would write the poem. (Laughter.) As I say, I had never written any poetry up to that time, but, just to show you what I could do without having had any practice whatever as a poet, I am going to give you the twelve lines that I wrote on that occasion. I think the weather inspired me. It was a touching little thing in its way, too (laughter).

Where snow had drifted o'er the land
I saw a sweet young mother stand;
  A babe was lying on her breast,
    Its little form
  Against herself she closely pressed,
    To keep it warm.

In later years I passed once more,
And saw her at her cottage door;
A boy was lying on her knee,
Her look was grim,
And, suffering Joshua, how she
Was warming him!

(Laughter and applause.)

I received a request here from somebody to give you some verses of my own entitled "The Man from York State." This poem is intended to bring out the characteristics of the man who always knows, when you tell him anything wonderful, of something more wonderful that happened back where he came from (laughter). It is told in the language of an old farmer down in Ohio. He said:

Old Bill Simpson come from York State; if a thing was big or fine
He could always think of something more surprisin' in that line;
When Joe Humphrey had his tumor, Bill looked at it, and, said he:
"It's a big one, I acknowledge, and I'm glad it ain't on me;
But I knew a man in York State, who'd a tumor that I'll bet
Was three times as big as this one—and it may be growin' yet."

If we raised a calf or punkin that was something extra, Bill
Always knew of one in York State that had been much grander still;
When Dave Henderson's wife left him, just because he'd killed her cat,
Bill said: "We'd a case in York State which was rather worse'n that;
Once, down there, a married woman left her husband's bed and board
On account of a loose window—that 'ud rattle when he snored."

You couldn't beat old York State, wet or dry, or night or day,
And we used to often wonder why Bill ever moved away;
When the Trask's folks had their triplets, Bill he stood and shook his head
While he fingered his chin whiskers, sort of thoughtful-like, and said:
"Well, yes, three's a lot! I dunno as I'd care for any more—
But I knew a York State fambly once that had a bunch of four."

When Hank Williams had the dropsy and was tapped by Doctor Grubb
The water they took from him was enough to fill a tub;
Bill was silent when we told him, and seemed thoughtful for a spell,
And we guessed we'd got him beaten; but, at last, he answered: "Well,
I don't want to do no castin' of reflections onto Hank,
But a man I knew in York State, when they tapped him, filled a tank!"

Poor old Bill! He's crossed the river, and I hope he's happy there.
Where he needn't deal with people that ain't always fair and square;
He'd a good heart in him—Bill had—done a lot of noble things.
But I'll bet you when they brought him out his crown and harp and wings
That he turned to old Saint Peter, or some angel bowin' low
As he said: "It's mighty splendid—York State beats it easy, though."

(Applause.)

To get back to this question of public utilities for a moment (laughter), you know, as Dean Cooley has said, troubles are sometimes thrust upon people. Some people inherit their troubles, and others borrow them. The most unfortunate people are those whose troubles are thrust upon them. An old gentleman, one of the plain people to whom certain eminent statesmen are fond of referring, belonged to this class—these people whose troubles are thrust upon them. In telling the story of his troubles, he said:

THE PEACEMAKER.

Twas just about a year ago that Fanny run away,
And left her ma and me alone—eloped with Philip Gray;
He'd come a-shinin' round her, off and on six months or so,
Though he seen I didn't like him—I took pains to let him know—
For I'd got a sort of notion that he thought it 'ud be fine
If he helped our girl inherit all this property of mine.

By a lot of good, hard workin' and by managin' things right
I have what is called a fortune—oh, of course, it's just a mite
As compared with Rockefeller's, though I thought, 'twixt me and you,
That our Fanny, bein' purty and well eddicated, too,
Had the right to look for some one who was higher up than Phil;
But it's wastin' time to argue when a woman says she will.

So they run off and got married. Ma was anxious from the start
To be kind of easy with 'em; said that Phil was good at heart;
But I sent 'em word to never set their feet inside my door;
I was through with both forever—yes, I said them words and more;
Made my will and left my money, every bit, to charity—
'Tother day they had a baby—and they've named him after me.

Lawsy, but it did seem lonesome after Fanny'd went away;
Ma she moped, and you could nearly see her brown hair turnin' gray.
And the silence used to kind o' get so loud I'd want to shout
Or slam dors or pound on something, thinkin' I could drownd it out—
Cute? By George, the little rascal's just as cute as he can be!
Not a single blemish on him, and they've named him after me.

If you'd told me things could ever be as gloomy round the place
As they've been since Fanny left us I'd of snickered in your face;
Why, the very sun has seemed to kind o' hate, somehow, to shine.
And last summer not a rosebud showed itself on Fanny's vine—
Little rascal! Everybody says he's got my nose and chin.
And he smiled as though he knew me when he seen me peepin' in.

Yes, ma took me up this mornin' and I've just destroyed my will;
Come to think the matter over, there are worse young men than Phil;
He's been doin' splendid, lately.—I believe that little tike
Must of knew I was his grandpa, for he looked up lovin' like
When they got the nurse to let me hold him—propped up on my knee—
Weighed eight pounds, and—have I mentioned that they've named him after me?

President-Elect Lee: Gentlemen, I was not advised as to the length of time which would be required by the speakers, and therefore I abruptly took a side-track. I will now resume my remarks. (Laughter.)

I wish to thank you, gentlemen, from the bottom of my heart for the honor conferred upon me by this Society. I wish to assure you of my best efforts to forward its ends. Boys, this is too great an organization to be a one-man organization, or a two or three-man organization. We must have team work if we are to go ahead or even if the Society is to maintain the standing which it has reached now. Are you with me?

Many voices: We are.

The *President:* Will you help me?

Many voices: We will.

The President: Thank you.

If there is no objection, I will declare passed a resolution of the Society thanking our able toastmaster and speakers for their very entertaining and instructive efforts in our behalf.

We will now sing Auld Lang Syne, all standing.

(The program was closed with the singing of the song.)

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY.

THE THEORY AND DESIGN OF STRUCTURES. By Ewart S. Andrews, B. Sc. Chapman & Hall, Ltd., London. 3rd ed.; cloth; 5½x8¾ in.; pp. 618. Price, 9/ net.

FURTHER PROBLEMS IN THE THEORY AND DESIGN OF STRUCTURES. By Ewart S. Andrews, B. Sc. Chapman & Hall, Ltd., London. Cloth; 5½x8½ in.; pp. 236. Price, 9/ net.

"A text-book for the use of students, draughtsmen, and engineers engaged in construction work," is the title page description of the first of these two volumes, which is a well written and well developed theoretical treatise giving considerably more space to the theory of stresses and to the elementary and fundamental consideration of the subject of beams and flexure than is the case with the familiar American text-books.

Although many of the subjects have been developed mathematically, graphical constructions have been used to a great extent, with the result that many of the formulae, especially those relating to deflections and fixed and continuous beams, are very simply and clearly deduced.

The first three chapters are devoted to principals of stresses and strains; forces, areas and moments. Graphical methods for the determination of moments of inertia and their adaptation to any section are very clearly presented and proved.

Chapter four deals with riveted joints and connections and gives a table of the British standard beam connections. A discussion of the methods of failure of riveted joints is also given.

Chapters five to ten treat the entire subject of beams for all conditions of supports and all cases of loading. Many practical examples applying to various formulae and constructions serve admirably to illustrate the theory.

The chapter on framed structures explains three methods of determining stresses and gives stress diagrams for the more common types of bridge and roof trusses.

The succeeding chapters treat briefly of the basic principles and theories for the design of columns and struts; suspension bridges and arches; masonry structures, such as dams, retaining walls, chimneys and arches; reinforced concrete. The chapter on the latter subject is little more than a description giving general ideas of the theories involved and some of the better known methods of construction used.

The portions of the book devoted to structural design and the illustrations of girder and truss bridges and steel skeleton buildings serve very well to show the great difference between English and American practice in both design and shop work. One wishes that a more complete analysis of various details had been given so that the reasons for some of this difference might be made clear.

Appendix I contains, in addition to an article on the subject of wind pressure, with the stress diagram for a roof truss considered in addition to the wind load on the windward side, a suction on the leeward side of the truss; discussions on the stresses in curved beams and the use of a parabolic template for drawing bending moment diagrams for uniformly loaded beams.

Appendix II contains tables giving the properties of British standard sections.

The second of these books, a first edition, deals very fully with the method of influence lines and deflections of framed structures, and contains chapters on stresses in redundant frames, arches, portals and wind bracing and secondary stresses in structures.

The adaptability of influence lines over the older and more common methods for calculating stresses is clearly shown and examples for various conditions of loading are given. The chapters illustrating the application of influence lines to fixed and continuous beams, arches and expansion bridges, together with those on stresses in arches, make this volume particularly useful and valuable to the designer of structures of any of these types of structures.

A very clear presentation of deflections of framed structures is given, the displacement diagram for a truss with unsymmetrical loading being an unusual feature in connection with the treatment of this subject.

The chapter on stresses in portals and wind bracing is a thorough discussion of the theory, but its application to practical problems is not so well presented as it is in several American texts.

The chapter on secondary stresses is for the most part a collection of American publications.

There are numerous typographical errors throughout this volume, none of which, however, are of a serious or misleading nature. E. S. A.

REINFORCED CONCRETE CONSTRUCTION. Vol. II. Retaining Walls and Buildings. Prepared in the Extension Division of the University of Wisconsin, by George A. Hool, of the University of Wisconsin. McGraw Hill Book Co., New York, 1913. 6x9 in.; 666 pp., including index; 411 text-figures and 33 plates, line drawings and half-tone cuts; cloth-bound. Price, $5.00.

This is a very complete work and is worthy of close study. The first volume of this series was issued in 1912 under the name of "The Elements of Structures" and was noted in the pages of our JOURNAL, Vol. XVII, page 282, March, 1912. The substance of Vol. I was the fundamental principle of reinforced concrete construction, and it has been adopted as a text-book in some of the engineering schools. This second volume treats of the design and construction of Retaining Walls (Part I) and of Buildings (Part II). The first part is subdivided into Chapter I, Theory of Stability; Chapter II, Design, and Chapter III, Construction.

In Part II of this work, Buildings, the text is divided into Section 1, Design, Chapters IV to XVII, inclusive; Section 2, Construction, Chapters XVIII to XXIV, inclusive, and Section 3, Estimating, Chapters XXV to XXVII, inclusive. An Appendix of 45 pages, the "Second Report of Joint Committee on Concrete and Reinforced Concrete," concludes this valuable book.

The Design of Buildings is considered under the subdivision of Floors, Types of Reinforcement, Roofs, Columns, Foundations, Walls and Partitions, Stairs, Elevator Shafts, Contraction and Expansion, Shears and Moments in Continuous Beams, Eccentric Loads in Columns, Wind Stresses, etc.

Under the head of Construction, Section 2, the subjects considered are: Materials, Forms, Placing Reinforcement, Proportioning, Mixing and Placing of Concrete, Finishing Concrete Surfaces, Waterproofing of Concrete, and with a chapter on Construction Plant by A. W. Ransome, which is full of interest and value.

The very important subject of Estimating, by Leslie H. Allen, is the subject of Section 3,—Unit Costs, Quantities, and a worked out "Example of an Estimate for a Concrete Building" as the concluding chapter. This enumeration of the sundry chapters of this book is presented to give one some idea of the scope and extent of this book. The multitude of illustrations makes the book that much more interesting and valuable. As a textbook for the engineering student, not the least valuable feature is the introduction of problems, to be worked out as an exercise to show the young man's understanding of the subject. These solved problems, it is presumable, are to be submitted to the instructor for verification and criticism. It is a great advantage that the present-day student has over those of a preceding generation, to have available such books as these by Professor Hool.

DESIGN OF PLATE GIRDERS. By Lewis E. Moore, B. S., C. E., Assoc. M. A. S. C. E., M. W. S. E., Associate Professor Structural Engineering, Massachusetts Institute of Technology. New York, 1913. McGraw-Hill Book Company. 280 pages; many illustrations and figures in text; cloth; 6½x9½ in. Price, $3.00 net.

The special value of this work is very aptly stated in the following words from the preface: "This book has been written with an idea of explaining clearly and in detail the reasons underlying designing, showing the assumptions made in given cases and giving as far as possible alternative methods, indicating what seems to be the best way and then allowing the student more or less of a choice as to the method to be pursued."

The work is carefully written and points are as clearly explained as possible, making it a good text-book for college students or for general reference in designing office or drawing room.

Having in mind the many text-books already written on the subject of stresses in girders, the author passes over this portion of the work quite briefly.

Probable action of rivets under stress is carefully considered and demonstrations given showing possible spacings for taking out minimum area for tension members.

The theory upon which girders are designed is discussed at some length. The usual assumptions are compared with the true formulae and the discussion brings out the variation between them, and shows approximately where the usual method may be safely used and where exact methods must be used to insure safe work.

A through and a deck girder are completely designed, the stresses being assumed. These chapters have the advantage of discussing stresses and sections under actual loads and using the specifications of one of the large railroad systems of the country. The usual assumptions and exact methods are again compared with the result that, excepting in extreme cases, the usual assumptions are generally found to err on the safe side. One point in which the author differs from the commonly accepted practice, however, is his advocacy of placing the thinner cover plate next to the flange angles and the thicker ones to the outside.

Design of box plate girders is discussed, fixed loads being assumed and an actual girder completely designed.

A very valuable chapter entitled "Shop hints for structural draftsmen" closes the body of the book. The shop and field work is too often overlooked in designing and detailing plate girders, and this chapter may well be read by all engaged in such work.

For the purpose of designing as nearly as possible under actual working conditions, the complete specifications for railroad bridges, of the New York, New Haven & Hartford Railroad of 1912, are reprinted, by permission of Mr. W. H. Moore, Engineer of Bridges of that company.

Sixty-five pages of tables and diagrams much used in designing girders close the book.

E. H. C.

THE PANAMA GATEWAY. By J. B. Bishop, Secretary Isthmian Canal Commission. New York, 1913. Charles Scribner's Sons. Cloth-bound; 6x9 in.; 459 pp.; 1 map and many illustrations, including a photo-engraving of "Geo. W. Goethals." Price, $2.50.

The author of this very interesting work had unusual opportunities for gaining the knowledge he shows of the operations at Panama. His statements, it is reasonable to suppose, are correct, and it would appear that only the detailed government reports might be more complete and enable a reader to have a more comprehensive knowledge of the subject. The matter is presented in a very pleasing and entertaining manner, as well as in a logical order.

In Part I is the History, from 1502 to 1879, of Columbus and His Search for a Hidden Strait, Balboa and His Discovery, Founding of Old Panama, First Transit Routes Across the Isthmus, and Early Projects for a Waterway, Awakening of American Interest, First Panama Railroad, etc.

Part II relates to the French Effort and Failure, 1879 to 1902, Methods of De Lesseps, First Visit to the Isthmus, Cost of Proposed Canal, Work on the Isthmus, and Life there in French Days, Return of De Lesseps to France, and Collapse of the Company, the New French Canal Company.

Part III continues the record, relating to the American Purchase and Control, 1902-1904, including the controversy between advocates of different routes, the Panama Revolution, and the Creation of the Republic of Panama. The preceding covers nearly one-half of the contents of the book.

In Part IV is given the Period of Construction, 1904 to 1915, with the beginnings of American Rule and Work, the Inefficiency of a Seven-Headed Executive Body, the Reorganization of the Commission with Mr. Stevens as Chief Engineer, and the visit of President Roosevelt. This is followed by the Third Commission, with the United States Engineers in charge. Succeeding chapters treat more in detail the canal construction, the Culebra Cut, the Gatun Dam and Locks, the Dams and Locks of the Pacific Side, the Sanitation of the Isthmus, how the results were secured, and the Evolutions of a "Benevolent Despotism." Many other matters are introduced in these chapters, which are of interest to engineers, including the value of the French property, comparison of French and American excavating machinery, and biographical notices of Veterans in the Canal Service, among which several are members of the Western Society of Engineers.

Finally Part V, The Completed Canal, gives much detailed information about the dams, locks and gates, movements of vessels through the canal, etc. Finally a copious index makes the information contained in the book so much more available. The author "has painted a picture of the work undertaken and accomplished in the Zone, which neither sacrifices conciseness to interest nor interest to accuracy." The "book bids fair to become the standard reference book concerning the Panama Canal."

DESRIPTIONS OF LAND. A Text-Book for Survey Students. By R. W. Cautley, D. L. S., B. C. L. S., A. L. S. New York, The Macmillan Company. Cloth; 5-in. by 7-in.; 90 pp.; ill. Price $1.00.

This is a thoroughly good book. The formidable alphabetical adornment of the author's name translated means, Dominion Land Surveyor, British Columbia Land Surveyor, Alberta Land Surveyor, for in the Anglicized neighboring country to the north of us surveyors must pass severe state examinations to procure a license and the abbreviations of the titles conferred seem to have the prescience of college degrees. When a man who has passed the severe ordeals imposed, and has worked for the number of years the author has worked, he should have something to say well worth while. That it is worth while is shown by the commendable brevity with which he has treated his subject. It reads like the writings of a man with something to say, who wishes to dispose of his subject just as soon as he has made it clear.

That the book was written by a Canadian does not make it of doubtful value to men in the United States. Only principles of common law are enunciated and the laws and statutes of the United States are based on the English common law. When the American reader substitutes "County Recorder" for "Registrar," or "Office of County Recorder" for "Land Titles Office," and "Manual of Instructions for Resurvey of the Public Lands of the United States" for "Dominion Lands Act," he makes all the changes required to render the book as serviceable south of, as it is intended to be north of, parallel of latitude 54° 40′ North.

The average lawyer, especially the lawyer in the country town, is ignorant of THE ERROR, something impressed upon the mind of the surveyor with increasing force as the years go by. The book therefore should be read by all lawyers and is an excellent little work a surveyor can present to a lawyer with whom he may have dealings, when the opinion of the lawyer clashes with the facts obtained by the surveyor. Another excellent book of the same class is "Landmarks and Boundaries," by Mulford. The library of the up-to-date surveyor cannot be hereafter considered complete without both these little books prepared by competent surveyors with abundant experience in problems overlapping the work of both lawyers and surveyors.

McC.

METEOROLOGY. A Text-Book on the Weather, the Causes of its Changes, and Weather Forecasting, for the Student and General Reader. Willis Isbister Milham, Ph. D. The Macmillan Co., N. Y. 1912. Cloth, 6 by 9 in. 549 pp. and 50 full-page charts, with 156 illustrations, including some full-page halftones. Price $4.50.

The author of this valuable and interesting treatise on the weather is one of the faculty at Williams College, and this book is the outcome of a course on Meteorology (an elective course), with the Junior and Senior students. It is essentially a text book, as would be evident on inspection of its arrangement, with marginal comments, the review questions, the topics for investigation, and practical exercises. This text is divided into numbered sections, which is of assistance for reference to some specific statement. As the book is intended for the general reader as well as student, it is hoped that these features of a text-book will not detract from the interest in the matter presented. While not an "elementary treatise," the book starts at the beginning and no previous knowledge of meteorology itself is anywhere assumed. References have been added at the end of the chapters, which include pamphlets and articles in periodical literature. These give the student the sources for further readings. Though the book has assumed some size and weight, and is full and complete enough for the general reader or student, some aspects of meteorology have not been considered. Thus there is no part of the book given to Mathematical Meteorology, Meteorology and Medicine, the influence of climate on man, nor a history of meteorology. The book does not attempt a complete elucidation of the subject, but it does contain a fairly full statement of the present state of the science.

In Part I there are eight chapters, relating to the atmosphere, the heating and cooling of the same, observations on its temperature, the pressure and circulation of the atmosphere and its moisture; also its secondary circulation, including cyclones, thunder showers, whirlwinds, and the like.

Part II, of five chapters, gives some consideration to climate, floods and river stages, and atmospheric electricity, optics and acoustics. The many illustrations through the book greatly enhance its value, and the tables furnish the basis of many interesting studies and comparisons.

Altogether the book is to be recommended to the general reader interested in natural science, or to the investigator in any special meteorological phenomena.

OBSERVATIONS IN METEOROLOGY. Relating to temperature, winds, atmospheric pressure, aqueous phenomena of the atmosphere, weather changes, etc.; being the results of a Meteorological Journal, kept for 19 years in Cambridgeshire, England, by the Rev. Leonard Jenyns, London, 1858.

This is an appropriate book to be associated with the preceding textbook on Meteorology. It is not a treatise, but a faithful record of daily observations for nineteen years, at one small place, Swaffham Bulbeck, between seven and eight miles E. N. E. of Cambridge and bordering on the Fens of that county. The elevation is low, about 20 ft. above sea level. The observations were limited to the thermometer, barometer, wind direction and precipitation. It is to be noted that these observations were made and the book written more than fifty years ago, and that much knowledge of meteorology has been built up in that time. Much valuable work has been done by the Weather Bureau of this country (and abroad), yet this journal of a painstaking observer at one small place in England is a valuable supplement to other writings on Meteorology.

Beginning with the Thermometer and Temperature in Chapter I, the subject of Winds occupies Chapter II, and Chapter III follows with the Barometer and Atmospheric Pressure. Chapter IV takes up the Aqueous Phenomena of the Atmosphere, which is followed by Thunderstorms in Chapter V, and General Observations on the weather in Chapter VI. Weather Prognostications (Chapter VII) is interesting as showing the lack of scientific basis for many forecasts, based on the phase of the moon and the like. Chapter VIII treats of Climate, more particularly of Cambridgeshire. As remarked above, the value of the book, apart from its personal narrative journalistic style, is as a source of study of observed meteorological phenomena, at one locality, over a long term of years.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts the following publications have been received:

NEW BOOKS.

- McGraw-Hill Book Co.:
    - Principles of Electrical Engineering, Harold Pender. Cloth.
    - Power Plant Testing, James A. Moyer. Cloth.
    - Standard Specifications for Structural Steel, Timber, Concrete, and Reinforced Concrete, John C. Ostrup. Cloth.
    - The Induction Motor, Henri B. De La Tour. Cloth.
    - Electrical Meters, Cyril M. Jansky. Cloth.
    - Design of Polyphase Generators and Motors, H. M. Hobart. Cloth.
    - Electrical Machine Design, Alexander Gray. Cloth.
    - Commercial Engineering for Central Stations, Williams & Tweedy. Cloth.
    - Engineering Thermodynamics, Charles E. Lucke.
    - Electric Traction for Railway Trains, E. P. Burch. Cloth.
    - Synchronous Motors and Converters, A. E. Blondel. Cloth.
    - Radiation, Light and Illumination, C. P. Steinmetz. Cloth.
    - Elementary Lectures on Electric Discharges, Waves and Impulses and other Transients, C. P. Steinmetz. Cloth.
- Sturgis & Walton Co.:
    - A Reader of Scientific and Technical Spanish, C. DeW. Willcox. Cloth.

MISCELLANEOUS GIFTS.

- C. L. Strobel, M. W. [illegible] E.:
    - Text-Book on Roads and Pavements, Spalding. Cloth.
    - Materials of Engineering, Thurston. Cloth. (3.)
    - Compound Locomotives, Woods. Cloth.
    - Graphic Statics, DuBois. Cloth.
    - Graphical Statics, Eddy. Cloth.
    - Trusses and Arches, Greene. 2 Cloth.
    - Mechanics of the Girder, Crehore. Cloth.
    - Vocational Education in Europe. Cloth.
    - Report on Vocational Training in Chicago and other Cities by a Sub-Committee of the City Club. Paper.

Alvord & Burdick:
  Report on Flood Protection for City of Columbus, Ohio. Paper.
Yellow Pine Manufacturers' Association:
  Yellow Pine Manual of Wood Construction, 1913. Pam.
New Hampshire Public Service Commission:
  Second Report for Period ending August 31, 1912. Cloth.
E. E. R. Tratman, M. W. S. E.:
  Annual Report of Harbor Commission, Montreal, 1912. Pam.
  Land Drainage, Bulletin Kansas State Agricultural College. Pam.
  Report of Water Commissioner on Water Supply of St. Louis. Pam.
  Some Facts about Treating Railroad Ties. Goltra. Parts 4, 5, 6. Pam.
  Rules and Regulations, Division of Works, Universal Exposition, San Francisco. Pam.
Iowa State Highway Commission:
  Service Bulletin, Vol. I, No. I, December, 1913. Pam.
E. S. Lund:
  Salt Lake City Building Ordinances, 1913. Pam.
New York Public Service Commission, First District:
  Annual Report, 1912, Part I. Cloth.
University of Illinois Engineering Experiment Station:
  Bulletins, Vols. 8 and 9, 1912-13. Cloth.
Illinois State Water Survey:
  Report for Year ending December 31, 1911. Cloth.

EXCHANGES.

American Society of Civil Engineers:
  Transactions, 1913. Paper.
Canada Department of Mines:
  Production of Copper, Gold, Lead, Nickel, Silver, Zinc and other Metals in Canada in 1912. Pam.
  Summary Report of Mines Branch, 1912. Pam.
Canadian Society of Civil Engineers:
  Transactions, January-June, 1913. Paper.
Tennessee Geological Survey:
  Bulletin No. 16, The Red Iron Ores of East Tennessee. Pam.
Wisconsin Railroad Commission:
  Sundry Decisions No. R. 683-725. Pams.
Canada Conservation Commission:
  Long Sault Rapids, St. Lawrence River. Cloth.
Michigan Engineering Society:
  Proceedings, 1910, 1911. Cloth.
American Society of Refrigerating Engineers:
  Transactions, 1912. Cloth.
Ontario Bureau of Mines:
  Nineteenth Annual Report, Part II. Cloth.
  Twenty-second Report, Part I, 1913. Cloth.
Maine Society of Civil Engineers:
  Proceedings, 1912. Pam.
Royal Society of New South Wales:
  Proceedings, September, November, 1912. Pams.
Nova Scotian Institute of Science:
  Proceedings and Transactions Session of 1909-1910. Pam.
Western Railway Club:
  Proceedings, Vol. 25, 1912-13. Cloth.
West Virginia Geological Survey:
  County Reports, Cabell, Wayne, and Lincoln Counties. Cloth.
American Institute of Chemical Engineers:
  The Relation of the Manufacturer to our Patent System. W. M. Grosvenor. Pam.

West Virginia Geological Survey:
Report on Marion, Monongalia and Taylor Counties. Cloth and maps.
New York Public Service Commission, First District:
Annual Report, 1911, Part III. Cloth.
New York Public Service Commission, Second District:
Sixth Annual Report, 1912, Vols. I and II. Cloth.
Engineering Association of New South Wales:
Proceedings, Vol. 27, 1911-12. Cloth.
Cleveland Engineering Society:
List of Members, Year Book, etc., 1913-14. Leather.
Wisconsin Geological and Natural History Survey:
The Geography and Industries of Wisconsin. Cloth.
Canada Conservation Commission:
Forest Protection in Canada, 1912. Cloth.
Massachusetts State Board of Health:
Annual Report, 1912. Cloth.
American Institute of Mining Engineers:
Transactions, Vol. 44, 1912. Paper.
Virginia Geological Survey:
Biennial Report on Mineral Production of Virginia for 1911 and 1912.
American Railway Master Mechanics' Association:
Proceedings, 1913. Cloth.
Boston Transit Commission:
Nineteenth Annual Report, 1913. Cloth.
Indiana Engineering Society:
Proceedings, 1912 and 1913. 2 Pams.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey:
Precious and Semi-Precious Metals in Arizona, New Mexico, Texas, Utah, Montana, Nevada, Idaho and Washington, in 1912. 6 pams.
The Production of Platinum and Allied Metals in 1912. Pam.
The Production of Petroleum in 1912. Pam.
Statistics of the Clay Working Industries in the United States in 1912. Pam.
The Production of Mineral Waters in 1912. Pam.
The Production of Metals and Metallic Ores in 1911 and 1912. Pam.
Copper in 1912. General Report. Pam.
U. S. Bureau of Standards:
Circular No. 42, Metallographic Testing. Pam.
U. S. Bureau of the Census:
Mortality Statistics, 1911. Cloth.
General Statistics of Cities, 1909. Cloth.
U. S. Coast and Geodetic Survey:
Results of Observations made at Magnetic Observatory near Honolulu in 1911 and 1912. Pam.
U. S. Bureau of Mines:
Technical Paper No. 41, Mining and Treatment of Lead and Zinc Ores in the Joplin District, Mo. Pam.
Technical Paper No. 51, Possible Causes of the Decline of Oil Wells. Pam.
Technical Paper No. 60, The Approximate Melting Points of some commercial Copper Alloys. Pam.
Technical Paper No. 30, Mine-Accident Prevention at Lake Superior Iron Mines. Pam.
Bulletin No. 71, Fuller's Earth. Pam.
U. S. Bureau of the Census:
Mortality Statistics, 1910. Cloth.

- Interstate Commerce Commission:
  - 24th Annual Report on the Statistics of Railways in the United States for year ending June 30, 1911. Cloth.
- U. S. Geological Survey:
  - Gold and Silver in 1912. Pam.
  - Precious and Semi-Precious Metals in Colorado in 1912. Pam.
  - Production of Natural Gas in 1912. Pam.
  - Precious and Semi-Precious Metals in California and Oregon in 1912. Pam.
  - Production of Cobalt, Molybdenum, Nickel, Tantalum, Tin, Titanium, Tungsten, Uranium, and Vanadium in 1912. Pam.
  - Zinc and Cadnium in 1912. Pam.
- U. S. Department of Agriculture:
  - Forest Service Bulletin No. 108, Tests of Structural Timbers. Pam.
- Isthmian Canal Commission:
  - Canal Record, Vol. VI, August 28, 1912-August 20, 1913. Cloth.
  - Annual Report for the Year Ending June 30, 1913. Paper and Maps.
- U. S. Bureau of Mines:
  - Miners' Circular No. 12. Safety in Tunneling. Pam.
  - Miners' Circular No. 13. The Use and Care of Miners' Safety Lamps. Pam.
  - Monthly Statement of Coal Mine Fatalities in the United States, September, 1913. Pam.
  - Bulletin No. 69. Coal Mine Accidents in the United States and Foreign Countries. Pam.
- U. S. Geological Survey:
  - Lead in 1912. Pam.
  - The Stone Industry in 1912. Pam.
- Smithsonian Institution:
  - Annual Report for the Year Ending June 30, 1912. Cloth.
- U. S. Bureau of Education:
  - Educational Directory, 1913. Pam.
- U. S. Chief of Engineers:
  - Annual Report, 1913, 3 Vols. Cloth.
- Secretary of Commerce:
  - Annual Report, 1913. Pam.
- U. S. Bureau of Mines:
  - Bulletin No. 70, A Preliminary Report on Uranium, Radium, and Vanadium.
- U. S. Bureau of Standards:
  - Technologic Paper No. 29, Variations in Results of Sieving with Standard Cement Sieves. Pam.
- U. S. Bureau of the Census:
  - Financial Statistics of Cities of over 30,000, 1911. Cloth.

MEMBERSHIP

Additions:

Pond, Frank H., Chicago	Member
Willett, Wm. M., Aurora, Ill.	Member

Transfers:

Bennitt, Ralph A., Chicago; Student to	Associate Member
Johnson, David J., Chicago; Student to	Associate Member
Jordan, Wm. F., Chicago; Associate Member to	Member
Mark, Perry C., Zanesville, Ohio; Junior to	Associate Member
Rieth, Wilhelm C., Montreal; Junior to	Associate Member
Schafmayer, A. J., Chicago; Junior to	Associate Member

Deaths:

Link, Rudolph. December 18, 1913

MAR 20 1914

VOL. XIX, No. 2. FEBRUARY, 1914

JOURNAL

OF THE

WESTERN SOCIETY

OF

ENGINEERS

CONTENTS

Retaining Walls—
J. W. Pearl 113
Manufacture of By-Product Coke—
T. V. Salt 173
Moderate Capacity Outdoor High-tension Substations—
H. W. Young 204
Memorial—
J. W. Johnson 227
Proceedings of the Society—
Minutes of Meetings 228
Book Reviews 229
Library Notes 231

CHICAGO

Published Monthly, Excepting July and August, by the Society,
1735 Monadnock Block.

Entered as Second-Class Matter March 3, 1896, at the Post Office at
Chicago, Ill., under Act of March 3, 1879.

Subscription Price, $3.00 per Volume of Ten Numbers.

50 Cents a Single Number.

Copyright, 1914, by the Western Society of Engineers.

WESTERN SOCIE OF ENGINEERS

1735 Monadnock Block, Chicago, Illinois.
Phone Harrison 945.

OFFICERS FOR 1914.

President.......................................E. H. Lee, Dearborn Station
First Vice-President.........................B. E. Grant, Room 207 City Hall
Second Vice-President........Ernest McCullough, 1302 Monadnock Block
Third Vice-President.........................G. F. Gebhardt, Armour Institute
Treasurer............................C. R. Dart, Room 700, 900 Michigan Ave.
Trustee...........................J. G. Giaver, 1 year, 1417 Railway Exchange
Trustee.....................F. E. Davidson, 2 years, 1448 Monadnock Block
Trustee.....................................H. S. Baker, 3 years, 402 City Hall

Past Presidents on the Board of Direction.

O. P. Chamberlain.......................108 So. La Salle St.
W. C. Armstrong.......................226 W. Jackson Blvd.
Albert Reichmann.........................72 W. Adams St.

ELECTRICAL SECTION

Executive Committee

F. J. Postel, Chairman; H. M. Wheeler, Vice-Chairman
G. T. Seely..1 year
P. B. Woodworth......................................2 years
E. W. Allen..3 years

BRIDGE AND STRUCTURAL SECTION.

Executive Committee

J. H. Prior..Chairman
J. W. Musham...................................Vice-Chairman
E. N. Layfield H. C. Lothholz I. F. Stern

HYDRAULIC, SANITARY AND MUNICIPAL SECTION

Executive Committee

W. D. Gerber..Chairman
G. C. D. Lenth...................................Vice-Chairman
W. W. DeBerard Douglas Graham Langdon Pearse

Secretary.............J. H. Warder

The Chanute Medals

The Board of Direction, W. S. E., desire to announce that the Octave Chanute Medals will be awarded for the most meritorious papers on Engineering subjects presented before this Society by members thereof during the year 1914.

Journal of the
Western Society of Engineers

VOL. XIX FEBRUARY, 1914. No. 2

RETAINING WALLS

FAILURES, THEORIES AND SAFETY FACTORS.

JAMES WARREN PEARL, M. W. S. E.

Presented December 1, 1913.

In presenting to the Society the examples and methods of design suggested in this paper, it may be well to state at once that the aim of the writer is not to present a diagnosis of all failures or a remedy for all the evils incident to the designing, construction, and maintenance of retaining walls, and he asks the indulgence of the audience in a few preliminary remarks indicating the necessity of revised rules for dimensions.

"It is stated as the experience of Voisan Bey, the Engineer-in-Chief of the Suez Canal, that he had never found a long line of quay wall which, on close inspection, proved to be perfectly straight in line and free from indication of movement."

In the same treatise this statement is made: "The most treacherous of all strata from the point of foundation for a quay wall is blue clay."

Not long ago an engineer in one of the principal cities along the shores of the Great Lakes stated that about nineteen out of twenty of the retaining walls he had examined were out of line in some respect, and his remarks implied that the engineering profession should be debited with the defects. The charge may be correct.

Not infrequently we hear of a retaining wall that has lived an upright and honest life for one or several years in accordance with all the rules of the best engineering society and then yields to some invisible temptation that the oldest and best members of the society cannot detect. And occasionally we hear of a wall that does not remain in good standing long enough for the builder to collect his pay for constructing it.

Are such results satisfactory engineering?

A structure supported upon a fluid is maintained in its position with a factor of safety of one; it may settle, deflect, tip or travel, but so long as it is supported its factor of safety is always one, whatever its position may happen to be.

A structure supported on a solid may ordinarily have a factor of safety of five, and in some cases twenty or more.

On the intermediate, earthy material, which may be called a semi-fluid or semi-solid, and upon which material most retaining walls are built, it appears to be but rational and prudent engineering to provide for a factor of safety intermediate between one and five, wherever the conditions and character of the semi-solid will permit. Allowance is thus made for unknown physical characteristics or contingencies, and a line of structures may be produced of which nineteen out of twenty will stand perpetually true to line and level.

It is believed to be the rule rather than the exception among engineers to design retaining walls without a thought as to the factor of safety they may have so long as the resultant pressure passes within the middle third of the base. Others will follow the good old easy rule of Trautwine and make the base 0.4 of the height, place the footing below the frost line, provide weep holes for the drainage of the back filling, and take a chance on the pressure on foundation and clogging of weep holes, either of which may cause disaster.

Malverd A. Howe, in his treatise on retaining walls, gives diagrams of forty walls, most of them designed and built by practical, or at least practicing, railroad engineers. The walls vary in height from 12 to 28 ft., with an average height of 20 ft. The bases are generally at depths of 4 to 5 ft. below the ground level, and the width of bases varies from 0.30 to 0.69 of the height, with an average of 0.49.

Many of these walls have moved from 2 in. to 15 in., and one whose base was 45% of its height and founded on rock has tipped over.

The record appears to represent "common practice" and a nearly even wager as to whether the walls would stand or yield; they may be said to have a factor of safety of approximately one.

If the designers of these walls required a steel superstructure, they would probably require a safety factor of four or five in the structure and a liberal allowance for impact and corrosion. In the steel structure the loads and the strength of steel are very definitely fixed, while the lateral pressure of filling and the bearing capacity of earth are neither well known nor constant. The writer is unable to understand the logic of such a wide variation of factors. The fact that the failure of the wall is less liable to kill as many people is not adequate reason for blindly following precedent and rules of thumb for retaining wall designs.

About two years ago a large gravity wall of roughly trapezoidal section, 40.6 ft. high and 18.5 ft. thick at the base (base 45% of height), constructed along the new New York State Barge Canal, failed by sliding and partially overturning when the back filling was about half completed. The initial movement of this wall was noticed, but back filling continued and about ten days later the final movement, covering a period of four hours, carried the toe outward 10 ft. and downward 4 ft., while the top moved outward 18 ft. The foundation of the wall was hard gravel with some boulders—too hard to drive piles—and the section that failed was about 400 ft. long; weight about 14,000 tons.

Assuming that the back filling was thoroughly saturated, weighed 120 lb. per cu. ft., and exerted hydrostatic pressure, it appears that the resultant pressure passed dangerously near the middle third limit, and the pressure upon the gravel at the toe was nearly 7,800 lb. per sq. ft. If the filling material was but partially saturated so that it would stand at a slope of 4 horizontal to 1 vertical, it would, according to common methods of estimating, exert a lateral pressure about 60% of the previous case, the resultant would fall well within the middle third of the base, and the pressure at toe would be only about 6,600 lb. per sq. ft.

It is reasonable to presume that the true condition lies between the limits given above, but let us examine another case.

Assuming that the back filling was dry, granular material of the same weight per cubic foot and having an angle of repose of 1½ horizontal to 1 vertical, the resultant pressure would pass into the quarter width from toe and the pressure at toe would be about 10,500 lb. per sq. ft. The writer concludes that the designer was so lazy an engineer that he applied the old rule of base equal to 0.4 of the height and allowed about 10% for "engineering and contingencies," or he may be a believer in the old adage, "Lazy folks take the most pains and fools work the hardest" and simply applied the practical knowledge acquired by long experience to dictate the lines of the structure. There are such engineers.

Failures of prominent structures are instructive to the engineering profession in proportion to the accuracy and amount of publicity given to them by the engineering press. The knowledge gained by this means always seems to take root a little deeper and live a little longer in the memory than the example of any successful structure or a mathematical digest of how it should be built. It is noticeable that in accounts in the technical papers, in the majority of cases tenderness pervades the account of details and charity prevails in the omission of the names of designers and builders. The law pronounces the newly made friend who sells the Logan Monument to a trusting rustic, a criminal, and the daily press publishes the name of the offender who collects the money that way. Then why should the name of the man or men who get the money by designing and building a wall that may fall upon and crush the owner or others be too sacred to mention? Is he or are they less criminal?

The wall mentioned above was to serve as an abutment for a railroad bridge, and the length of the abutment indicates that it was for a railroad of at least four tracks. The pressure added at the toe of the wall by the bridge and its load would be considerable because the bridge seats were near the face of the wall, but the amount cannot be computed with the data available.

The engineering paper in which the failure was recorded attributes the disaster to the ***dynamic effect of dropping scraper bucket loads of earth in making the fill.*** As the bucket loads probably weighed less than four tons and consisted of loose earth dropped on loose earth, it is difficult to understand how the four tons moved the 14,000 tons beyond a safe range of elasticity, and more difficult to comprehend how the "dynamic effect" was prolonged through the period of four hours occupied in moving an average distance of about 12 ft.

The application of mathematics to designing engineering structures has been greatly extended in the last quarter century, and most of the engineers who "graduated" that long ago have failed to advance with the tide, and even may have forgotten how to use more than the rudiments in the limited field of their practice. Such engineers and those who graduated from the front end of the chain are inclined to scoff at the formulae of the professors and young engineers because they can neither use nor understand them. I urge young men in the profession to humor those older men of easy-engineering virtue who base their claim to competence on the number of years they have practiced and dictate designs without rule or reason, but don't forget your mathematics,—acquire more when possible and apply it when permitted.

When the president of a company calls for the present value of a sinking fund compounded thrice annually at 3.9% per annum, the gentleman with prolonged practice is liable to have other urgent demands on his time until he can consult the cub-engineer in the back room. Had he been called upon for the dimensions required for a beam, an arch, or a retaining wall he could have answered at once. The greatest difference in the two requisitions lies in the fact that the president and chief clerk might be able to check up on the curve of the sinking fund.

The many failures of walls and dams have caused some engineers to require that the resultant pressure pass through or back of the center of the base,—this is another extreme.

Of the many theories regarding the internal pressures existing in earth, that advanced by Rankine about the year 1857 is most generally accepted in this country. In Europe, I am informed that Coulomb's theory of a plane of rupture or wedge of least resistance is preferred. Readers desiring to investigate all the theories will find a very complete list of reference in "Retaining Walls for Earth," by Malverd A. Howe, Fifth Edition, 1911, page 99.

As Rankine's theory is general, being but a special case of the general subject of internal stress in a homogeneous body, which condition of stress is represented by an ellipse or an ellipsoid, it is considered the most reliable. It has the additional merit that it may be applied to a fill or a foundation, while the Coulomb formula is limited to pressure produced by filling.

In the general case the equations of Rankine may be applied to a ball of putty, a block of rubber, or a bar of steel, but for the special case of a granular material, the tensile strength or adhesion is considered to be zero, and the shearing strength is limited to the frictional resistance between the particles and is represented by the angle of repose of the material.

This noted authority states: "Earth work gives way by *slipping* or sliding of its parts on each other; and its stability arises from resistance to the tendency to slip. In a mass of earth, as commonly understood, resistance arises partly from friction between the grains and partly from their mutual adhesion; which latter force is considerable in some kinds of earth such as clay, especially when moist. But adhesion of earth is gradually destroyed by the action of air and moisture, and changes of weather, and especially alternate freezing and thawing; so that its friction is the *only* force which can be relied upon to produce permanent stability."

In his *Civil Engineering,* 1877, page 324, he states: "There is a mathematical theory of the combined action of friction and adhesion in earth; but for want of precise experimental data, its practical utility is doubtful."

Various writers during the past 50 years have assailed the theories of Rankine with little effect. Sir Benjamin Baker made experiments with boards placed at various angles and found that the lateral pressure was quite as much when the inclined board was placed at an angle of 1½ to 1 as when it was placed at half that angle; and used the results to discredit earlier theories. In the diagrams it will be shown, especially in Fig. 3, that the results are what should be expected from Coulomb's or Rankine's formulae when properly interpreted.

Professor Weyrauch presented a theory about 35 years ago and confidently endorsed it in the following words: "It is free from all the objections which may be urged against all others and can be used with confidence."

Another writer quotes an experiment with fine shot which gave results nearly double those computed by Coulomb's theory, and, I presume, Rankine's, thus discrediting both. Experiments by E. P. Goodrich indicate a great variation between the angle of repose and angle of internal friction in many materials, and this may account for the unexpected results in the experiments with shot.

A writer on masonry construction in this country attacks Rankine's theories and quotes as follows,—"but for want of precise experimental data its practical utility is doubtful," to indicate that the renowned professor had but little confidence in his own equations. This mutilation of a paragraph covering an entirely separate subject, and using but half of it to discredit the theories applied to a condition devoid of adhesion, was an unfortunate mis-step that was retracted by the omission of it in later editions, but without apology.

In developing the special formulae for earth pressures Rankine, in his *Applied Mechanics,* on page 212, says: "Previous researches on this subject are based on some mathematical artifice or assumption, such as Coulomb's 'Wedge of Least Resistance.' Researches so based, although leading to true solution in many special problems, are both limited in the application of their results, and unsatisfactory in a scientific point of view. I propose, therefore, to investigate the mathematical theory of the *frictional* stability of a granular mass, without the aid of any artifice or assumption, and from the following sole

PRINCIPLE:

> *The resistance to displacement by sliding along a given plane in a loose granular mass, is equal to the normal pressure exerted between the parts of the mass on either side of that plane, multiplied by specific constant.*
>
> The specific constant is the *coefficient of friction* of the mass, and is the tangent of the *angle of repose*."

As previously mentioned, the angle of repose and the angle of internal friction are not always the same. This is a physical characteristic of various materials not recognized 50 years ago, which affects the constant used by Rankine without vitiating his mathematical processes or the theory of conjugate pressures.

A very general method of determining the maximum pressure of filling against a retaining wall is to assume a series of planes passing through the heel of the wall, compute the weight above each plane and consider it to act on an inclined surface with a coefficient of friction equal to the internal friction in the material. The back of the wall may have any inclination desired. The top of the filling may likewise have any desired slope and the direction of the pressure upon the back of the wall may be assumed in any direction to suit the fancy of the designer. But a number of planes must be used and a number of directions for the pressure upon the wall must be computed to determine the maximum. The process is tedious.

To illustrate a simpler method I will assume a simple case, that of a wall with a vertical back retaining a level fill as shown in Fig. 1:

Let $B\ C$ represent a plane passing through the heel at B and making any angle β with $A\ B$ greater than zero and less than the angle $A\ B\ D$. It will be shown later that there may be considerable variation in the value of β without material variation in the result, or that an irregular or curved surface of rupture is quite accurately represented by the plane $B\ C$.

Let W equal the weight of the filling above the plane $B\ C$, and P the pressure on the back of the wall, both per lineal foot of wall:

Let w equal the weight per cubic foot and ϕ equal the angle of repose of the filling material, and tangent ϕ will be taken as the coefficient of internal friction of the material.

Then $W = \dfrac{wh^2}{2} \tan \beta$ for a wall of height h.

The forces W and P will be resolved into components parallel and perpendicular to $B\ C$ as shown in Fig. 2, and the value of P

will be determined by drawing the line *a d*, making the angle ϕ with the normal *a c* to *b c*.

The total force acting downward paralled to $B\ C = W \cos\beta$, must equal the summation of the resistances, so we have:

$$W \cos\beta = W \sin\beta \tan\phi + P \cos\beta \tan\phi + P \sin\beta.$$

$$\text{Whence } P = \frac{wh^2}{2} \tan\beta \left(\frac{\cos\beta - \sin\beta\tan\phi}{\sin\beta + \cos\beta\tan\phi}\right)$$

$$= \frac{wh^2}{2}\left(\frac{\cot\phi - \tan\beta}{\cot\phi + \cot\beta}\right) \ldots\ldots\ldots\ldots\ldots \text{Eq. 1.}$$

For this particular case the value of P could be written at once from Fig. 2, as follows:

$$P = W \tan(90 - \phi - \beta) = \frac{wh^2}{2} \tan\beta \cot(\phi + \beta) \ldots\ldots\ldots \text{Eq. 2.}$$

The complete diagram of forces is easier to understand and preferable for discussion.

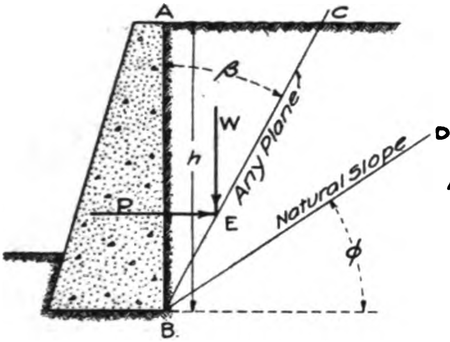


Fig. 1

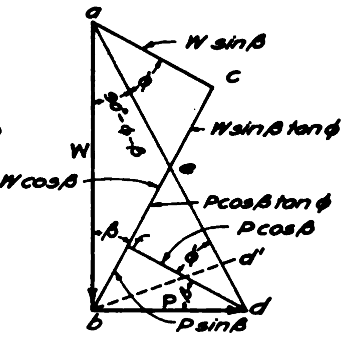


Fig. 2

Assume now that ϕ is the angle of internal friction (the natural slope may have the same or any other value), and that for a given homogeneous earth, ϕ equals 33° 40′ or is the angle corresponding to a slope of 1½ horizontal to 1 vertical:

For ϕ constant and β variable the factor in Equation 1 becomes: $\left(\frac{\cot\phi - \tan\beta}{\cot\phi + \cot\beta}\right)$

For $\beta =$	10°,	15°,	20°,	25°,	30°,	40°,	45°,	50°
Factor =	0.187,	0.235,	0.267,	0.284,	0.285,	0.247,	0.200,	0.132

The maximum value is for $\beta = 28°\ 10'$ and is 0.286.

This shows that a single value may represent any plane between $\beta = 20°$ and $\beta = 40°$ with a maximum variation of only 10% and an average variation of about 6%; or that the summation of an irregular or curved surface of rupture with various angles between 20° and 40° may be *closely represented by a straight line* when the value of ϕ is uniform throughout the mass.

In Fig. 3 the values of the above factors are plotted from the zero line in their true angular position in the quadrant and produce the curve *a b c*.

For β constant and equal to 28° 10′ and ϕ variable, the factor

$$\left(\frac{\cot\phi - \tan\beta}{\cot\phi + \cot\beta}\right)$$ in Equation 1 becomes:

For ϕ=	10°,	15°,	20°,	25°,	30°,	40°,	50°,	60°
Factor=	0.68,	0.57,	0.48,	0.40,	0.33,	0.21,	0.11,	0.02

This shows that the value of ϕ is the predominating function in the expression. The values are plotted in their true angular position in Fig. 3 and form the curve *d e f*.

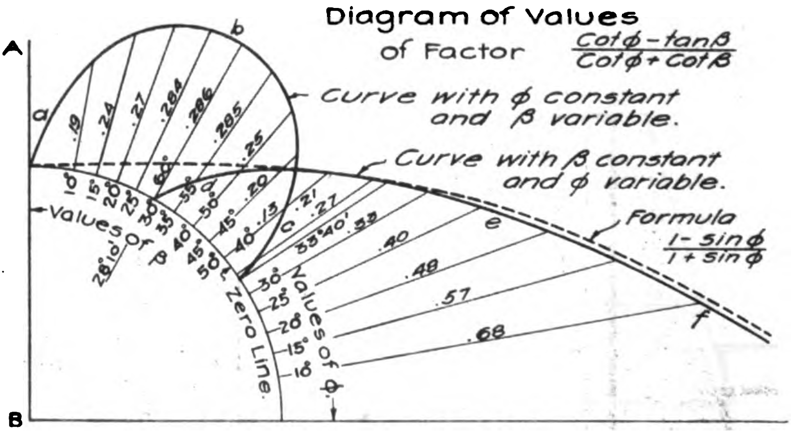


Fig. 3

Sir Benjamin Baker's experiments are quoted as showing hardly any difference in the lateral pressure of earth, whether the board was placed at an angle of ½ to 1 or horizontal. The result is precisely what should be expected if the board was not lubricated, and the report does not indicate that such an anomalous condition was used in the tests. The slope of ½ to 1 corresponds to a value of 26° 40′ for our β and it will be noted that a variation of only 2/286 should be found between values of 28° 10′ and 25°, so the variation betwen 28° 10′ and 26° 40′ would be only about *one-third of one per cent.*

For all positions of the board at an angle greater than 28° 10′ from the vertical our formula indicates that the lateral pressure should be constant unless the coefficient of friction between the material and the board was materially less than the coefficient of internal friction of the material.

Notice that Equation 1 is based on homogeneous material and not on a planed board or any other abnormal condition. If the coefficient of friction in the material below the plane was less, it might affect the value of the lateral pressure, but if it was greater it would not.

Returning to Equation 1 and applying Calculus, with ϕ constant for any given material:

$$\frac{dP}{d\beta}=\frac{wh^2}{2}\,\frac{(\cot\phi+\cot\beta)\,(-\sec^2\beta)-(\cot\phi-\tan\beta)\,(-\operatorname{cosec}^2\beta)}{(\cot\phi+\cot\beta)^2}$$

Placing this equal to zero and reducing:

$$-\frac{\cot\phi}{\cos^2\beta}-\frac{\cot\beta}{\cos^2\beta}+\frac{\cot\phi}{\sin^2\beta}-\frac{\tan\beta}{\sin^2\beta}=0$$

Reducing $-\cot\phi\sin^2\beta-\cot\beta\sin^2\beta+\cot\phi\cos^2\beta-\tan\beta\cos^2\beta=0$

or $-\cot\phi\tan^2\beta-\cot\beta\tan^2\beta+\cot\phi-\tan\beta=0$

or $\cot\phi\,(1-\tan^2\beta)-2\tan\beta=0$

or $\cot\phi=\dfrac{2\tan\beta}{1-\tan^2\beta}=\tan 2\beta$

$$\therefore\beta=\frac{1}{2}(90-\phi)=45-\frac{\phi}{2}$$

Substituting this value of β in Equation 1 there results:

$$P\max=\frac{wh^2}{2}\left(\frac{\cot\phi-\tan\frac{1}{2}(90^\circ-\phi)}{\cot\phi+\cot\frac{1}{2}(90^\circ-\phi)}\right)=\frac{wh^2}{2}\left\{\frac{\dfrac{\cos\phi}{\sin\phi}-\dfrac{1-\cos(90-\phi)}{\sin(90-\phi)}}{\dfrac{\cos\phi}{\sin\phi}+\dfrac{\sin(90-\phi)}{1-\cos(90-\phi)}}\right\}$$

$$=\frac{wh^2}{2}\left\{\frac{\dfrac{\cos^2\phi-\sin\phi+\sin^2\phi}{\sin\phi\cos\phi}}{\dfrac{\cos\phi-\sin\phi\cos\phi+\sin\phi\cos\phi}{\sin\phi-\sin^2\phi}}\right\}$$

$$=\frac{wh^2}{2}\,\frac{(1-\sin\phi)^2}{\cos^2\phi}=\frac{wh^2\,(1-\sin\phi)^2}{2\,(1-\sin^2\phi)}$$

Whence:

$$P\max=\frac{wh^2}{2}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)\text{ ....Eq 3.}$$

This is the familiar form of Rankine's equation for the lateral pressure of earth against a vertical wall when the top of the earth is level, although developed by an entirely different line of reasoning and mathematics.

Substituting the value of β in Equation 2 there results:

$$P\ \text{max} = \frac{wh^2}{2} \tan\left(45^\circ - \frac{\phi}{2}\right) \cot\left(\phi + 45^\circ - \frac{\phi}{2}\right)$$

But $\cot\left(45^\circ + \frac{\phi}{2}\right) = \tan\left(45^\circ - \frac{\phi}{2}\right)$

Hence, $$P\ \text{max} = \frac{wh^2}{2} \tan^2\left(45^\circ - \frac{\phi}{2}\right) \ldots\ldots\ldots\ldots\ldots \text{Eq. 4.}$$

This is the favorite form used in European countries for computing the lateral pressures of earth against a vertical retaining wall.

Equation 4 may be also obtained from Equation 3 by the following substitution:

$$\frac{1 - \sin\phi}{1 + \sin\phi} = \left\{\frac{\dfrac{1 - \cos(90 - \phi)}{2}}{\dfrac{1 + \cos(90 - \phi)}{2}}\right\} = \frac{\sin^2 \frac{1}{2}(90^\circ - \phi)}{\cos^2 \frac{1}{2}(90^\circ - \phi)} = \tan^2\left(45^\circ - \frac{\phi}{2}\right)$$

Since these four equations are identical in value and Equation 3 is true for a vertical wall and horizontal top, it follows that any variation from a vertical wall and horizontal top will cause a variation in the value of β for maximum pressure, and it also follows that the popular method of bisecting the angle between the angle of repose and the vertical, and using the wedge between such a bisecting plane and the wall to determine the maximum pressure on the wall is true *only when the angle of internal friction is the same as the angle of repose and the top of the fill is level.*

For a superimposed load of W' pounds per square foot on the level earth, the factor $W'h \tan\beta$ would be added to the weight W, in the preliminary equation; the center of pressure would move to the right, and the value of β would be greater than $\left(45 - \frac{\phi}{2}\right)$. Similar changes would result from a fill sloping upward and away from the wall, and opposite variations would result from a fill sloping downward and away from the wall. Walls with the back inclined toward or away from the fill may be considered as planes removing or adding a known weight to W. In fact, the method is believed to be perfectly general.

With corrections to Equation 1 to cover the variations from the case illustrated, the value of β giving the maximum P may be determined in one operation by Calculus, or a series of imaginary planes may be computed and the maximum selected. For the latter method, the curves in Fig. 3 indicate that the value of β in the vicinity of $45° - \frac{\phi}{2}$ may, for a given material, vary 5° without material change in the force P, so it will not be necessary to compute sections at intervals closer than 10° to secure fairly accurate results.

The value of the coefficient of internal friction, as has been shown, is the predominating argument in all methods of computation and should be determined with care and for the most unfavorable variations of saturation, shock, and vibration that may be anticipated in any case. Engineers are urged to read and study the report of E. P. Goodrich, in the Transactions of the American Society of Civil Engineers, Vol. 53, 1904, regarding these phenomena, and to collect and report similar data.

When no better data are available, the angle of repose may be used with caution.

Some writers maintain that the friction of the earth upon the back of the wall should be considered in the design. In some instances this may be justifiable, but cases have been reported which show a settlement of the wall away from the filling material, which is in a measure plausible when the pressure upon the foundation is excessive and the adhesion within the filling is considerable. It is not safe to depend upon this friction in ordinary cases.

The friction upon the back of the wall may be allowed for in the diagram Fig. 2 by drawing the line $b\ d'$ making the angle $d\ b\ d'$ equal to the angle of friction between the earth and wall. This line $b\ d'$ will then give the direction and amount of P with the friction considered, and Equation 2 should be revised to express it.

With the friction on the back of the wall neglected, to be consistent, the direction of P must be taken normal to that surface; in the case of a wall with the back stepped and having vertical faces, the weight of the earth above the steps may be omitted from W and added to the weight of the wall without material error.

To determine the point of application of P, locate the center of gravity of the earth and surcharge, or superimposed load, above the plane $B\ C$, Fig. 1, and the intersection of a vertical through this center of gravity with the plane $B\ C$ will locate the point desired.

In the preparation of standards for the design of subways in the city of Chicago, where much of the work must be done in the most unreliable of earths for foundation purposes,—blue clay of various degrees of saturation and plasticity,—the writer has not deemed it prudent to accept "thumb rules" for the lateral pressure on walls, or the building code for permissible pressures on footings.

It does not appear logical to place a load of 3000 or 4000 lb. per sq. ft. on a building foundation, whether it be located at a depth of 4 ft. or 40 ft. below surrounding surfaces of earth. The irregular floors in many existing buildings are sufficient evidence that the rule is wrong or that the engineers made gross errors in computing the loads; equally irregular movement in subway construction would result in incalculable damage to adjacent buildings, some of which are already in as unsightly a condition as any critic could desire.

The theory of Rankine has been used for earth pressures because it may be applied to either walls or foundations, or to surfaces at any other angles when the value of the internal friction of the material has been determined and direct pressure on contiguous earth is known.

In relatively stiff material, that is, those earths having a high coefficient of friction, the range between the active pressures and passive resistances permits a factor of safety in design that will approach the usual allowance for structural material; but in the softer, plastic materials it is sometimes difficult to secure a factor of safety of one for all the variations of loads.

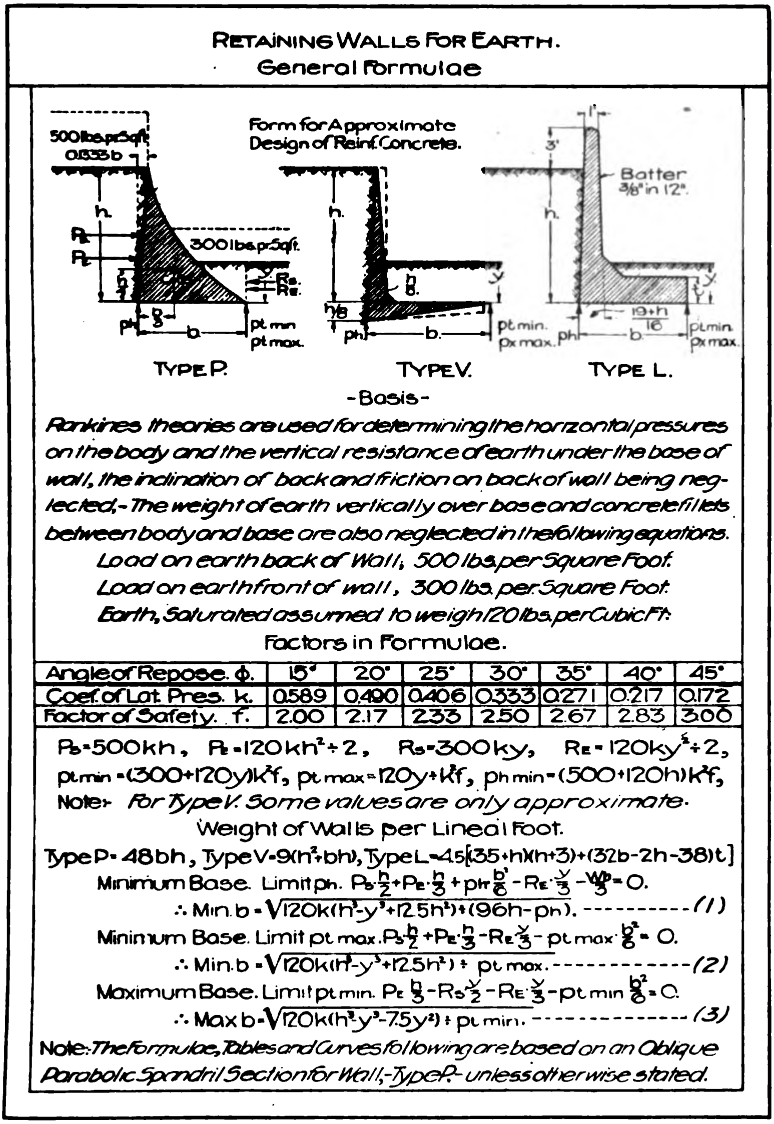
In designing retaining walls with a variable load on either or both sides of the wall, the first guess on the dimensions will be wide of the mark if any limits are placed on the foundation pressures at heel and toe. If, in addition to this, a great variety of material is to be provided for, which may be the same or different underneath and back of the wall, and a margin of safety as liberal as can be obtained is sought, the "cut and try" method becomes very tedious.

All attempts to express the conditions required for a practical wall section resulted in equations too complicated for ordinary use. To produce a workable equation, an impracticable wall was assumed, as represented by Type P, Fig. 4, which illustrates a wall whose cross section is an oblique parabolic spandril,—the batter on the back being equal to 13⅓% of the base.

The area of this section = 1-3 b h, so the weight per lineal foot for a concrete wall = 48 b h, and the center of gravity of the section is at a distance of one-third the base and one-quarter the height from the heel, all of which materially simplifies equations for computing pressures at both edges of the base.

The units used in computations are pounds, feet, square feet, and cubic feet, and a section of wall one foot long. The symbols in equations and text are as follows:

Height of earth retained, above base....................h
" " " above toe ....y
Width of base..b
Total pressure on back of wall, due to surface load............P_s
" " " " " " " " earth retained ....P_E
" " " front " " " " surface load ....R_s
" " " " " " " " earth above toe ....R,



RETAINING WALLS FOR EARTH.
General Formulae

-Basis-

Rankines theories are used for determining the horizontal pressures on the body and the vertical resistance of earth under the base of wall, the inclination of back and friction on back of wall being neglected,- The weight of earth vertically over base and concrete fillets between body and base are also neglected in the following equations.

Load on earth back of Wall; 500 lbs. per Square Foot.
Load on earth front of wall, 300 lbs. per Square Foot.
Earth, Saturated assumed to weigh 120 lbs. per Cubic Ft.

Factors in Formulae.

Angle of Repose. ϕ.	15°	20°	25°	30°	35°	40°	45°
Coef. of Lat. Pres. k.	0.589	0.490	0.406	0.333	0.271	0.217	0.172
Factor of Safety. f.	2.00	2.17	2.33	2.50	2.67	2.83	3.00

$P_S = 500kh$, $P_E = 120kh^2 \div 2$, $R_S = 300ky$, $R_E = 120ky^2 \div 2$,
$p_t\,min = (300 + 120y)k^2f$, $p_t\,max = 120y \div k^2f$, $p_h\,min = (500 + 120h)k^2f$,
Note:- *For Type V. Some values are only approximate.*

Weight of Walls per Lineal Foot.

Type P = $48bh$, Type V = $9(h^2 + bh)$, Type L = $4.5[(35+h)(h+3) + (32b - 2h - 38)t]$

Minimum Base. Limit ph. $P_S \cdot \frac{h}{2} + P_E \cdot \frac{h}{3} + p_h \frac{b^2}{6} - R_E \cdot \frac{y}{3} - \frac{Wb}{3} = 0.$

$\therefore$ Min. $b = \sqrt{120k(h^3 - y^3 + 12.5h^2) \div (96h - p_h)}$. ---------- (1)

Minimum Base. Limit pt max. $P_S \cdot \frac{h}{2} + P_E \cdot \frac{h}{3} - R_E \frac{y}{3} - p_t\,max \cdot \frac{b^2}{6} = 0.$

$\therefore$ Min. $b = \sqrt{120k(h^3 - y^3 + 12.5h^2) \div p_t\,max}$. ------------ (2)

Maximum Base. Limit pt min. $P_E \frac{h}{3} - R_S \frac{y}{2} - R_E \cdot \frac{y}{3} - p_t\,min \frac{b^2}{6} = 0.$

$\therefore$ Max $b = \sqrt{120k(h^3 - y^3 - 7.5y^2) \div p_t\,min}$. -------------- (3)

Note: *The Formulae, Tables and Curves following are based on an Oblique Parabolic Spandril Section for Wall,-Type P.- unless otherwise stated.*

Fig. 4

Intensity of Pressure on Foundation at heel	p_h
" " " " " at toe	p_t
Thickness of base for wall of Type L	t
Angle of internal friction (or angle of repose)	k
Coefficient determined by $\frac{1-\sin\phi}{1+\sin\phi}$	f
Factor of safety	ϕ

The values of k and the factors of safety desired for various materials represented by ϕ are given in Fig. 4.

It is always desirable to have the resultant pressure upon the foundation material pass the base as near its center as the variable loads, surrounding conditions, and element of cost will permit; and when the supporting material is so plastic or perfectly granular that it is liable to flow, the values of p_h and p_t should be such as to permit some disturbance in the surrounding material by excavations relieving pressure, or additional loads on foundations near by without danger. In other words, there are many reasons for the determination of p_h and p_t and applying a factor of safety.

The values of p_h and p_t should always be positive, so a diagram of the pressures on a safe foundation will always be represented by a trapezoid in which p_h and p_t are the vertical components of the parallel sides, and b is the horizontal distance between them; a line drawn diagonally through two opposite corners of the trapezoid will then divide the foundation pressure into two parts, one of which is fully represented by p_h and b and the other by p_t and b.

The minimum pressure under the heel of a wall should be ample to resist any tendency to flow produced by the earth retained and its surface load, and is expressed by the formula,

$$p_h \text{ min.} = (500+120h)\ k^2 f.$$

This places a minimum limit on the width of base which is given by Equation 1, Fig. 4.

This Equation 1 (Fig. 4) is deduced by taking the moment of all forces about a center located in the base of the wall at a point one-third b from the toe. This center for moments is selected to eliminate the moment of that portion of the pressure on the foundation represented by p_t.

The minimum pressure under the toe of the wall should likewise be ample to resist any tendency to flow produced by the earth at the toe of the wall and the surface load at and to the right of the toe, and is expressed by the formula

$$p_t \text{ min} = (300+120y)\ k^2 f.$$

This places a maximum limit on the width which is given by Equation 3, Fig. 4.

This Equation 3 (Fig. 4) is obtained by taking moments about

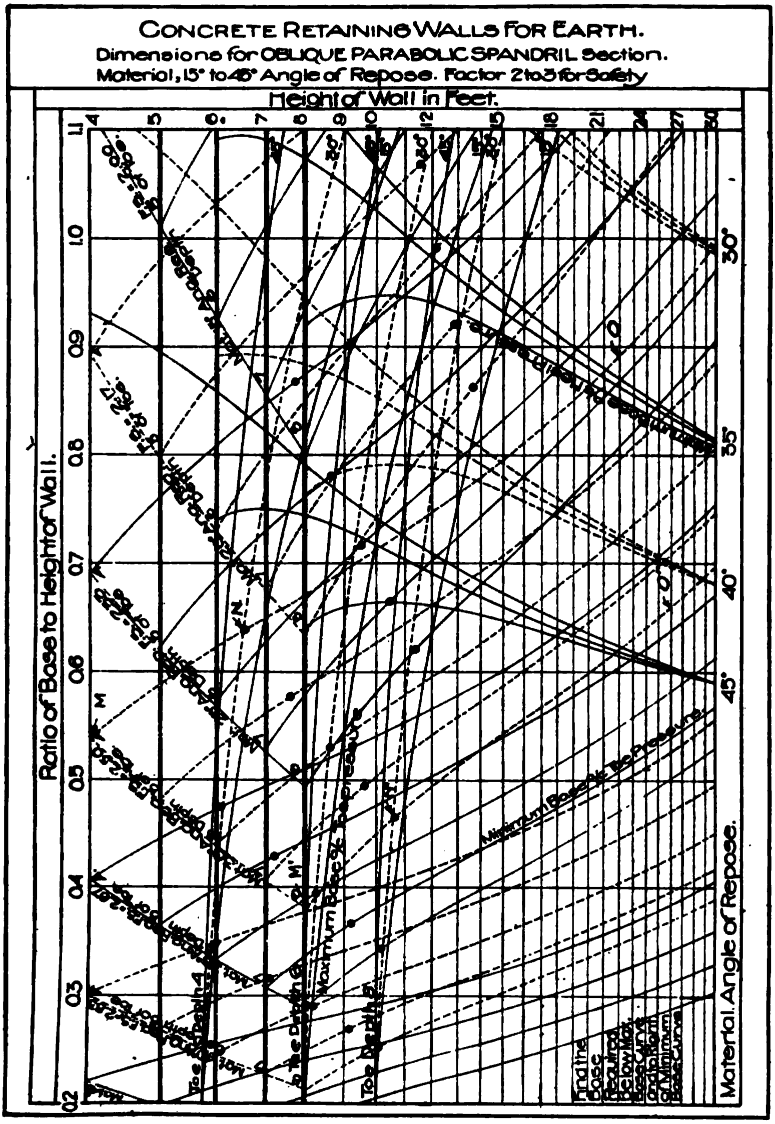

CONCRETE RETAINING WALLS FOR EARTH.
Dimensions for OBLIQUE PARABOLIC SPANDRIL Section.
Material, 15° to 45° Angle of Repose. Factor 2 to 3 for Safety
Height of Wall in Feet.
4
5
6
7
8
9
10
12
15
18
21
24
27
30
Ratio of Base to Height of Wall.
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
Material. Angle of Repose.
30°
35°
40°
45°
Maximum Base & Toe Pressure
Minimum Base & Toe Pressure
Toe Depth 4
Toe Depth 6
Toe Depth 8
M
M'
N
Find the Base Required below Max. Base Curve and above Minimum of Minimum Base Curve

Fig. 5

a center located in the base of the wall at a point one-third b from the heel, so that the weight of the wall and that portion of the foundation pressure represented by p_h are eliminated.

The maximum pressure under the toe of the wall should not exceed the safe bearing value of the earth as determined by the formula

$$p_t \text{ max.} = 120y \div k^2f.$$

This places a minimum limit on the width of base which is expressed by Equation 2 (Fig. 4) when moments are taken on the line of base at a point one-third b from the heel.

An equation may also be written to provide against sliding on the base as follows:

$P_s f + P_x f = W_x f - R\ K'$, in which K' is the coefficient of friction between the base and the supporting material. This reduces to

$$\text{Min. base} = \frac{1.25\ k\ f}{k'\ h}(h^2 - y^2 + 8.33h) \ldots\ldots\ldots\ldots\text{Eq. 5.}$$

In all the preceding equations the base has been assumed to be horizontal; for inclined or stepped bases the corrections required will be apparent to competent designers, and these notes are not intended for the use of indifferent members of the profession.

Figures 5, 6 and 7* have been produced from Fig. 4, and Equations 1, 2 and 3.

These diagrams give the bases required for walls in terms of the height, for heights 4 to 30 ft. and depths of toe 4 to 8 ft., resting upon and retaining materials having angles of internal friction (angle of repose) from 15° to 45° and weighing 120 lb. per cu. ft. when subjected to either of the surface loads stated in Fig. 4.

Fig. 5 is for factors of safety as shown in table in Fig. 4.

Fig. 6 is for a factor of safety of one.

Fig. 7 is for a factor of safety of one at the toe and zero pressure at the heel.

The character of material will, for convenience, hereafter be designated by its angle of internal friction.

To illustrate the use of tables in designing a wall, assume that an embankment 18 ft. high, of 30° material weighing 120 lb. per cu. ft. is to be retained by a wall resting on similar material at a depth of 4 ft. below the surface at toe; that the surface load on the back of the wall may be 500 lb. per sq. ft.; on the front of the wall the surface load may be 300 lb. per sq. ft., and that a factor of safety of 2.50 is desired. Enter the diagram Fig. 5 on the line of "Mat. 30°—F. S.=2.50," "Depth of Toe 4 ft." at *M*, follow the curve down and to the right to dot *N*, which gives 0.64 as the widest base that will have the desired safety against inflow of earth at toe; follow on down the curve to *O*, opposite height of wall 22 ft., which gives 0.89 as the least width that will have the desired safety against outflow of earth at toe.

The dots indicate the heights of wall and depths of toe at which

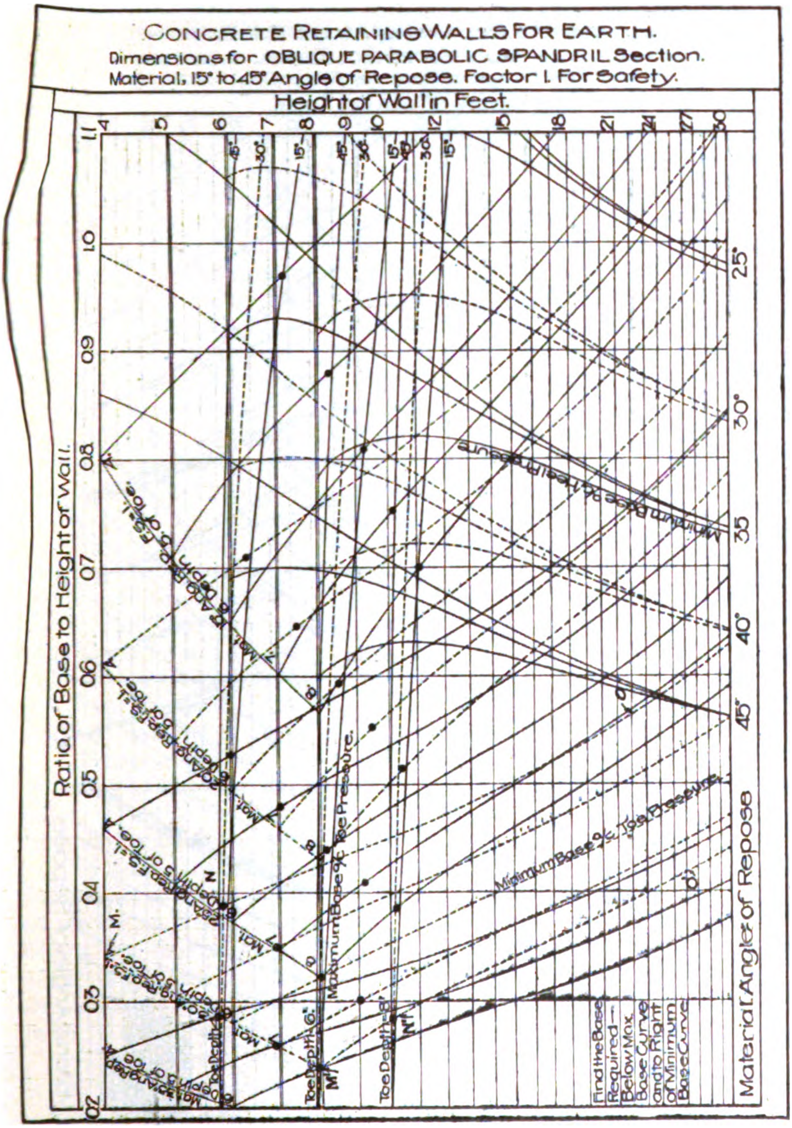

CONCRETE RETAINING WALLS FOR EARTH.
Dimensions for OBLIQUE PARABOLIC SPANDRIL Section.
Material, 15° to 45° Angle of Repose. Factor 1. For Safety.
Height of Wall in Feet.
4
5
6
7
8
9
10
12
15
18
21
24
27
30
Ratio of Base to Height of Wall.
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
Material Angle of Repose
25°
30°
35°
40°
45°
15°
30°
45°
Minimum Base % Heel Pressure
Maximum Base % Toe Pressure
Minimum Base % Toe Pressure
M
N
Toe Depth 6"
Toe Depth 18"
Find the Base Required — Below Max. Base Curve and to Right of Minimum Base Curve

Fig. 6

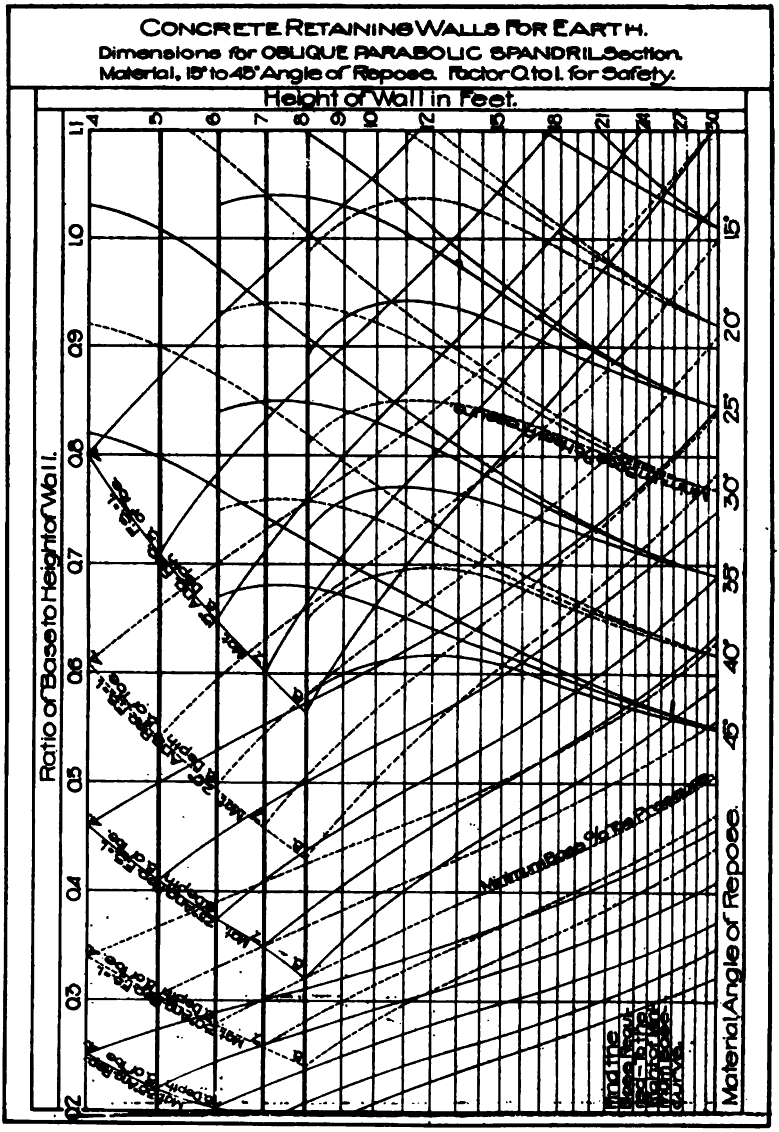

CONCRETE RETAINING WALLS FOR EARTH.
Dimensions for OBLIQUE PARABOLIC SPANDRIL Section.
Material, 15° to 45° Angle of Repose. Factor 2 to 1. for Safety.
Height of Wall in Feet.
4
5
6
7
8
9
10
12
15
18
21
24
27
30
Ratio of Base to Height of Wall.
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
15°
20°
25°
30°
35°
40°
45°
Material Angle of Repose.
Minimum Base % Toe Pressure
Find the Base Result

Fig. 7

both conditions of p_t may be satisfied, and the curves for heel pressure indicate that it is not practical to secure the desired safety factor at the heel of a wall. These curves, however, are useful for comparison with what may be obtained as shown in Fig. 6.

Next, assume a depth of toe 8 ft. and all other conditions as before. Starting from M', at a height of 10.7 ft., at N', both conditions for p_t will be satisfied by a wall whose base is 0.46 of its height; and on down to O' a wall whose base is 0.66 of its height above base, will afford a factor of safety of 2.5 at the toe with all conditions as assumed.

Referring now to Fig. 6, which is for a factor of safety of one, and using a depth of toe of 4 ft. and all other conditions as before, following the same letters it is found that a wall with a base equal 0.39 of its total height will satisfy both conditions for p_t, its net height will be only 1.9 ft. and its base 2.7 ft. The base required at a depth of 22 ft. at $O=0.57\times22=12.54$ ft. for a net height of 18 ft.

For the case at a depth of 8 ft., the width of base required will be $0.42\times26=10.9$ ft. for the same net height of 18 ft.

With the dimensions selected from the diagrams for Type P wall, the approximate dimensions for trapezoidal or other sections may be selected by constructing curves for equivalent walls, as shown for walls of Type V, or Type L, Fig. 8, or by other means.

The form of Type V is not practical, but it is convenient in making computations, and a practical wall for reinforced concrete work will result by reducing somewhat the width of base and adding to the thickness as indicated by dotted lines on base and stem.

Type L is a practical wall for reinforced concrete material in subway construction, as its construction requires the minimum width of excavation and interference with other street occupancy, and the parapet is required to protect adjacent areas.

For connections to elevated railways, the base may be reversed to come under the fill, or an inverted T section may be used; in either case the weight of earth over the base in the fill should be included with the weight of the wall in the computations.

In reinforced concrete, the thicknesses indicated in Fig. 4, of $h\div8$ for V walls and $(19+h)\div16$ for L walls will generally be as strong as required, depending somewhat on the dimensions of the fillets, but they will not be as heavy as required on walls over about 12 ft. high; for walls of greater height, it is advisable to increase the thickness and diminish the reinforcing rather than extend the base to secure stability.

The Conversion Diagrams in Fig. 8 solve the following problems, with the oblique parabolic spandril section as a modulus:

1. Determines the dimensions and location of the center o gravity of all the walls of the V type, from 6 to 30 f high and from 2 to 4 ft. thick, having the *same base an weight as Type P.*

   EXAMPLE: Assume a wall of Type P, 13 ft. high wit base $= 0.40h$.

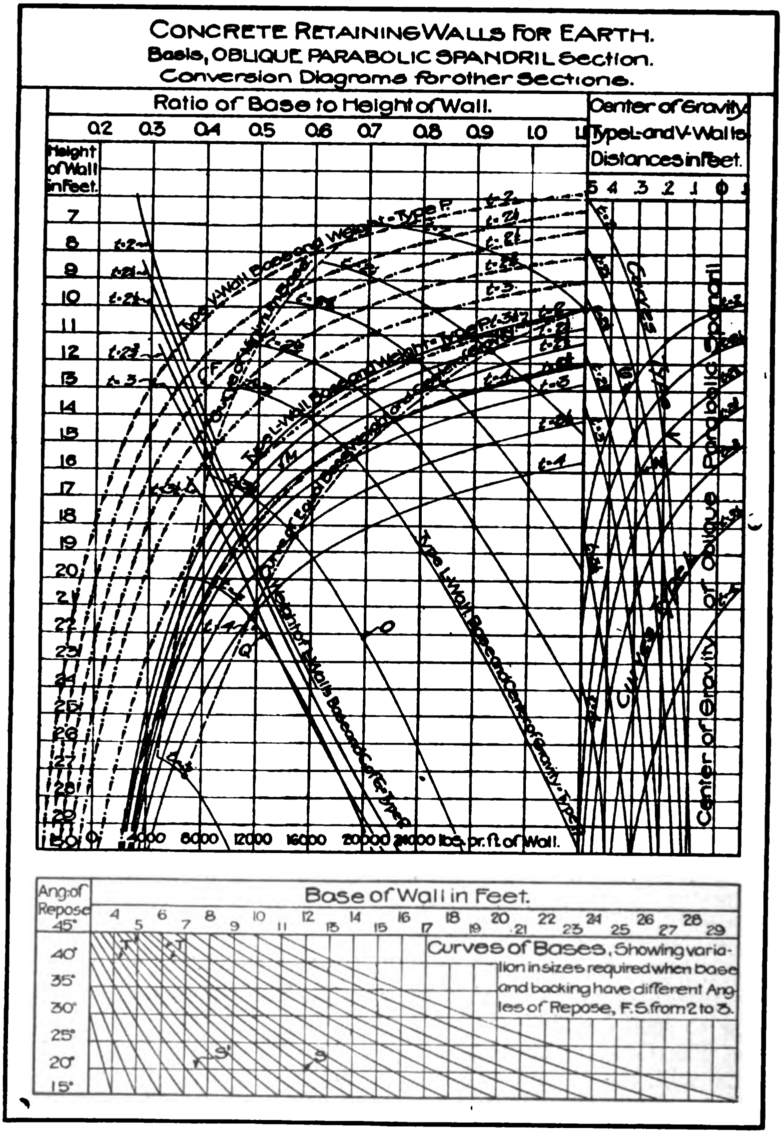

CONCRETE RETAINING WALLS FOR EARTH.
Basis, OBLIQUE PARABOLIC SPANDRIL Section.
Conversion Diagrams for other Sections.
Ratio of Base to Height of Wall.
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Height of Wall in Feet.
7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Center of Gravity Type L- and V-Walls Distances in Feet.
5 4 3 2 1 0
Type V-Wall Base and Weight - Type P.
Type L-Wall Base and Weight - Type P.
Curves of Equal Base Weight
Height of Walls Base and C of G - Type P.
Type L-Wall Base and Center of Gravity - Type P.
Center of Gravity of Oblique Parabolic Spandril
Curves
0 4000 8000 12000 16000 20000 24000 lbs. pr. ft. of Wall.
Ang. of Repose 45°
Base of Wall in Feet.
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
40° 35° 30° 25° 20° 15°
Curves of Bases, Showing variation in sizes required when base and backing have different Angles of Repose, F.S. from 2 to 3.

Fig. 8

At the intersection of $h=13$, and ratio 0.40 at point *F*, thickness at heel is indicated by the dot and arrow curve to be 2.5 ft., and following the horizontal line to the right at the intersection of curve for Type V=2.5 ft. at *G*, the location of center of gravity is found to be 0.36 ft. to the left of the center of gravity of the wall Type P, or

$(13 \times 0.40 \times 0.333) - 0.36 = 1.37$ ft. from the heel.

2. Walls of Type V with same base and center of gravity as Type P are not practical.
3. Wall of Type V with same base, weight, and center of gravity as Type P are not possible.
4. Determines the dimensions and location of center of gravity of all walls of the L type, within the limits stated above, having the *same base and weight as Type P.*

   Example: Assume a wall of Type P, 16 ft. high, with base $= 0.55h$.

   At intersection of $h=16$ and ratio of 0.55 at *M*, the full line curve for walls of equal base and weight gives thickness 2.5 ft.; and following the horizontal lines to the right at *N* on curve for L walls 2.5 ft. thick, the location of center of gravity is given at 0.28 ft., to the left of the center of gravity of a wall Type P, or

   $(16 \times 0.55 \times 0.333) - 0.28 = 2.65$ ft. from the heel.
5. Determines the dimensions and weights per lineal foot of all walls of the L type, within the range of the diagram, having the *same base and center of gravity (horizontal) as a wall of Type P.*

   Example: Assume a wall of Type P 22 ft. high with base $0.70h$.

   At intersection of $h=22$ and ratio 0.70 at *O*, the full line curve for walls of equal base and center of gravity gives thickness $t=3.5$ ft., and upon the same horizontal at the intersection of the weight curve for thickness 3.5 ft. at *Q* read downward to weight scale—13,000 lb. per lin. ft.—"more or less."
6. For every ratio of base to height there is an L type wall whose base, weight and center of gravity coincides with the corresponding values for walls of Type P; these values are located at the intersection of curves for equal base and weight and equal base and center of gravity, for the same thickness, as indicated by dots; the curve drawn through these dots establishes a dividing line for the designer that may be utilized as follows: If the intersection of a height and ratio line falls above this curve, the center of gravity of any equivalent wall will be to the left of that of the oblique parabolic spandril section taken as a modulus, and if it falls below this curve the weight will be less than the modulus.
7. Another curve drawn through the upper left ends of the

curves for equal base and center of gravity locates a limit below which this condition of equality is impossible.

8. The curves at the bottom of Fig. 8 are for use when the earth underneath and back of wall have different characteristics, as represented by the angles of internal friction (or repose).

   If the material under a wall is represented by 40° and the material retained is represented by 20° the width of base with a factor of 2.17 for a wall 12 ft. high with the base 6 ft. below the surface (see Fig. 5), should be 12 ft. if foundation material was the same. Enter the curves for bases at the intersection of lines for 12 ft. and 20° at *S* and follow the curve up to the line of 40° and find the width of base at *T*, to be 6.25 ft.

   If the materials in base and backing are reversed, other conditions being the same (from Fig. 5), the base should be $0.34 \times 12 = 4$ ft. Enter the curve of bases at the intersection of 40° and 4 ft. at *T'* and follow the curve down to the line of 20° and find the width of base at *S'* to be 7.5 ft.

   When different materials are to be considered, the conversion of bases should always precede the conversion of walls.

The preceding operations will give the approximate dimensions required for a wall, and to minimize the labor and probability of error in final design the following tables are offered.

Ordinarily the friction between a wall and the earth it rests upon, is greater than the internal friction in the earth, so the tangent of ϕ will be used as the resistance to sliding on the base.

Then $\dfrac{(P_E+P_S-R)\,f}{W} = \tan\theta$ should not exceed the tangent of ϕ given near the top in Table 1.

The values of f are given in Fig. 4, R in Table 1, P_E in Table 2, P_S in Table 3, $P_E+P_S=P_T$ in Table 4, and W will be determined from the dimensions selected as the preliminary design. If no surface load or surcharge is provided for, P_S will be omitted.

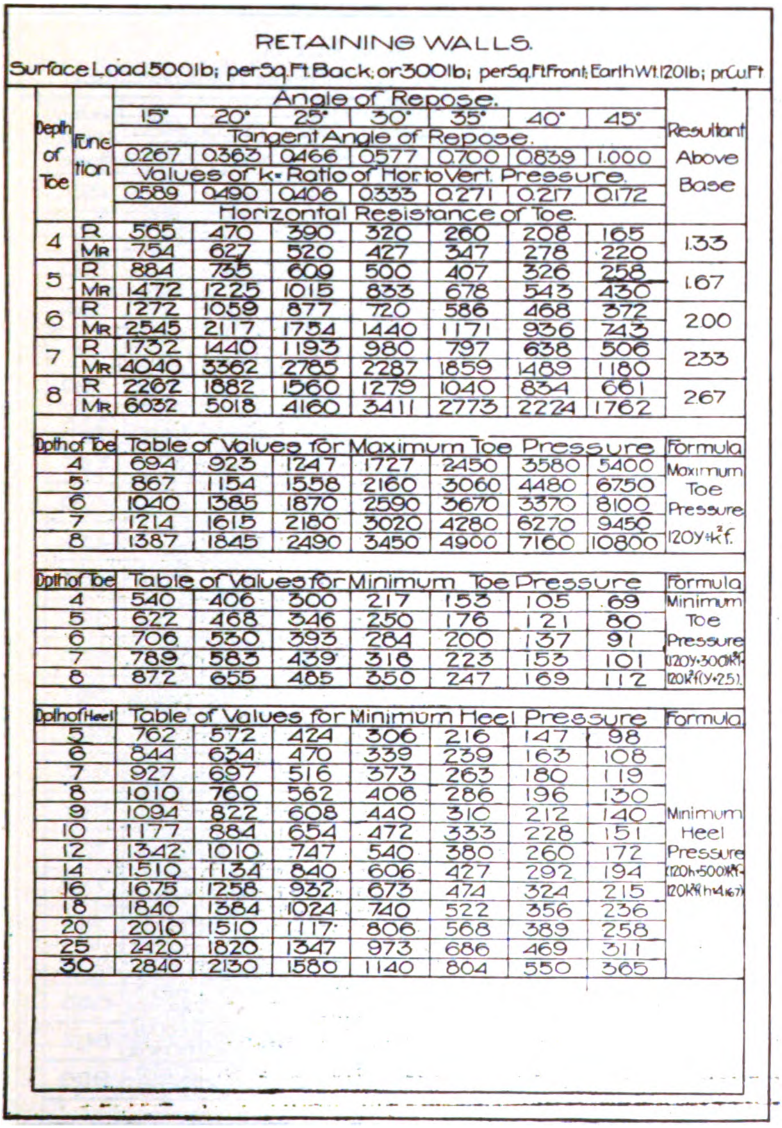
If the material retained or at toe weighs less than 120 lb. per cu. ft., P_E and R should be correspondingly reduced.

If the result exceeds the tangent of ϕ the base of the wall should be inclined or stepped at an angle equal $(\theta-\phi)$.

The use of the moments M_W, M_E, M_S and M_T and the values of toe and heel pressures will be apparent to all who have a thorough understanding of Fig. 4, and should not be used by others.

Figures 5 and 6 may be used to determine the approximate dimensions of walls with other surface loads and other weights of earth as follows:

EXAMPLE: Assume a wall to hold an embankment 18 ft. high



RETAINING WALLS.

Surface Load 500 lb; per Sq. Ft. Back; or 300 lb; per Sq. Ft. Front; Earth Wt. 120 lb; pr Cu. Ft.

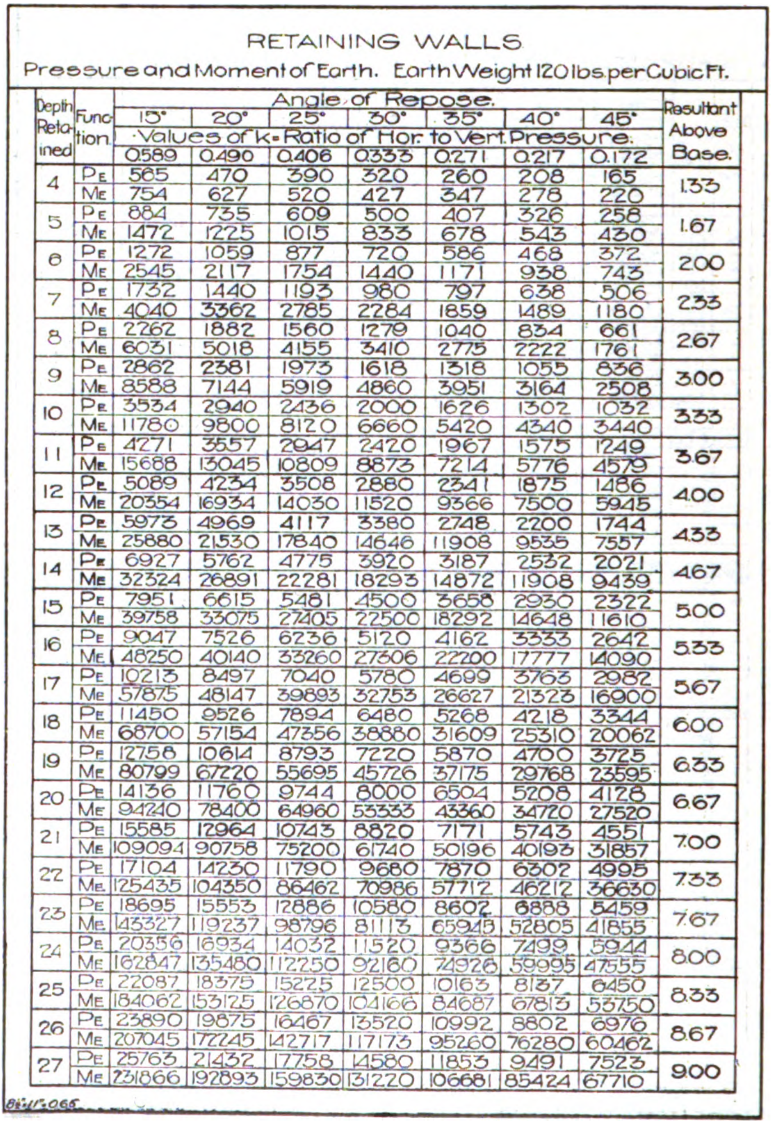
Depth of Toe	Function	Angle of Repose.							Resultant Above Base
		15°	20°	25°	30°	35°	40°	45°	
		Tangent Angle of Repose.							
		0.267	0.363	0.466	0.577	0.700	0.839	1.000	
		Values of k = Ratio of Hor. to Vert. Pressure.							
		0.589	0.490	0.406	0.333	0.271	0.217	0.172	
		Horizontal Resistance of Toe.							
4	R	565	470	390	320	260	208	165	1.33
	MR	754	627	520	427	347	278	220	
5	R	884	735	609	500	407	326	258	1.67
	MR	1472	1225	1015	833	678	543	430	
6	R	1272	1059	877	720	586	468	372	2.00
	MR	2545	2117	1754	1440	1171	936	743	
7	R	1732	1440	1193	980	797	638	506	2.33
	MR	4040	3362	2785	2287	1859	1489	1180	
8	R	2262	1882	1560	1279	1040	834	661	2.67
	MR	6032	5018	4160	3411	2773	2224	1762	

Dpth of Toe	Table of Values for Maximum Toe Pressure							Formula
4	694	923	1247	1727	2450	3580	5400	Maximum Toe Pressure $120y \div k^2 f$.
5	867	1154	1558	2160	3060	4480	6750	
6	1040	1385	1870	2590	3670	3370	8100	
7	1214	1615	2180	3020	4280	6270	9450	
8	1387	1845	2490	3450	4900	7160	10800	

Dpth of Toe	Table of Values for Minimum Toe Pressure							Formula
4	540	406	300	217	153	105	69	Minimum Toe Pressure $(120y+300)k^2f-$ $120k^2f(y+2.5)$.
5	622	468	346	250	176	121	80	
6	706	530	393	284	200	137	91	
7	789	583	439	318	223	153	101	
8	872	655	485	350	247	169	112	

Dpth of Heel	Table of Values for Minimum Heel Pressure							Formula.
5	762	572	424	306	216	147	98	Minimum Heel Pressure $(120h+500)k^2f-$ $120k^2f(h+4.167)$
6	844	634	470	339	239	163	108	
7	927	697	516	373	263	180	119	
8	1010	760	562	406	286	196	130	
9	1094	822	608	440	310	212	140	
10	1177	884	654	472	333	228	151	
12	1342	1010	747	540	380	260	172	
14	1510	1134	840	606	427	292	194	
16	1675	1258	932	673	474	324	215	
18	1840	1384	1024	740	522	356	236	
20	2010	1510	1117	806	568	389	258	
25	2420	1820	1347	973	686	469	311	
30	2840	2130	1580	1140	804	550	365	

Table 1



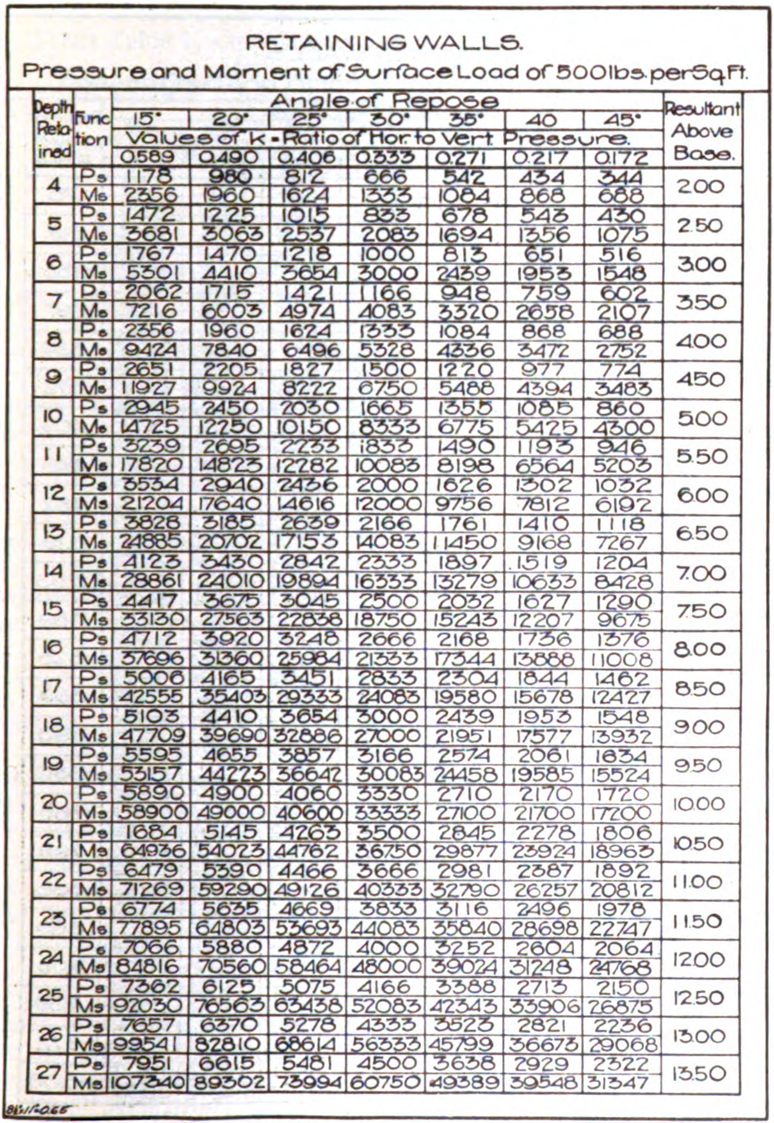
RETAINING WALLS

Pressure and Moment of Earth. Earth Weight 120 lbs. per Cubic Ft.

Depth Retained	Function	Angle of Repose.							Resultant Above Base.
		15°	20°	25°	30°	35°	40°	45°	
		Values of k = Ratio of Hor. to Vert. Pressure.							
		0.589	0.490	0.406	0.333	0.271	0.217	0.172	
4	PE	565	470	390	320	260	208	165	1.33
	ME	754	627	520	427	347	278	220	
5	PE	884	735	609	500	407	326	258	1.67
	ME	1472	1225	1015	833	678	543	430	
6	PE	1272	1059	877	720	586	468	372	2.00
	ME	2545	2117	1754	1440	1171	938	743	
7	PE	1732	1440	1193	980	797	638	506	2.33
	ME	4040	3362	2785	2284	1859	1489	1180	
8	PE	2262	1882	1560	1279	1040	834	661	2.67
	ME	6031	5018	4155	3410	2775	2222	1761	
9	PE	2862	2381	1973	1618	1318	1055	836	3.00
	ME	8588	7144	5919	4860	3951	3164	2508	
10	PE	3534	2940	2436	2000	1626	1302	1032	3.33
	ME	11780	9800	8120	6660	5420	4340	3440	
11	PE	4271	3557	2947	2420	1967	1575	1249	3.67
	ME	15688	13045	10809	8873	7214	5776	4579	
12	PE	5089	4234	3508	2880	2341	1875	1486	4.00
	ME	20354	16934	14030	11520	9366	7500	5945	
13	PE	5973	4969	4117	3380	2748	2200	1744	4.33
	ME	25880	21530	17840	14646	11908	9535	7557	
14	PE	6927	5762	4775	3920	3187	2532	2021	4.67
	ME	32324	26891	22281	18293	14872	11908	9439	
15	PE	7951	6615	5481	4500	3658	2930	2322	5.00
	ME	39758	33075	27405	22500	18292	14648	11610	
16	PE	9047	7526	6236	5120	4162	3333	2642	5.33
	ME	48250	40140	33260	27306	22200	17777	14090	
17	PE	10213	8497	7040	5780	4699	3763	2982	5.67
	ME	57875	48147	39893	32753	26627	21323	16900	
18	PE	11450	9526	7894	6480	5268	4218	3344	6.00
	ME	68700	57154	47356	38880	31609	25310	20062	
19	PE	12758	10614	8793	7220	5870	4700	3725	6.33
	ME	80799	67220	55695	45726	37175	29768	23595	
20	PE	14136	11760	9744	8000	6504	5208	4128	6.67
	ME	94240	78400	64960	53333	43360	34720	27520	
21	PE	15585	12964	10743	8820	7171	5743	4551	7.00
	ME	109094	90758	75200	61740	50196	40193	31857	
22	PE	17104	14230	11790	9680	7870	6302	4995	7.33
	ME	125435	104350	86462	70986	57712	46212	36630	
23	PE	18695	15553	12886	10580	8602	6888	5459	7.67
	ME	143327	119237	98796	81113	65945	52805	41855	
24	PE	20356	16934	14032	11520	9366	7499	5944	8.00
	ME	162847	135480	112250	92160	74926	59995	47555	
25	PE	22087	18375	15225	12500	10163	8137	6450	8.33
	ME	184062	153125	126870	104166	84687	67813	53750	
26	PE	23890	19875	16467	13520	10992	8802	6976	8.67
	ME	207045	172245	142717	117173	95260	76280	60462	
27	PE	25763	21432	17758	14580	11853	9491	7523	9.00
	ME	231866	192893	159830	131220	106681	85424	67710	

86-11-065

Table 2

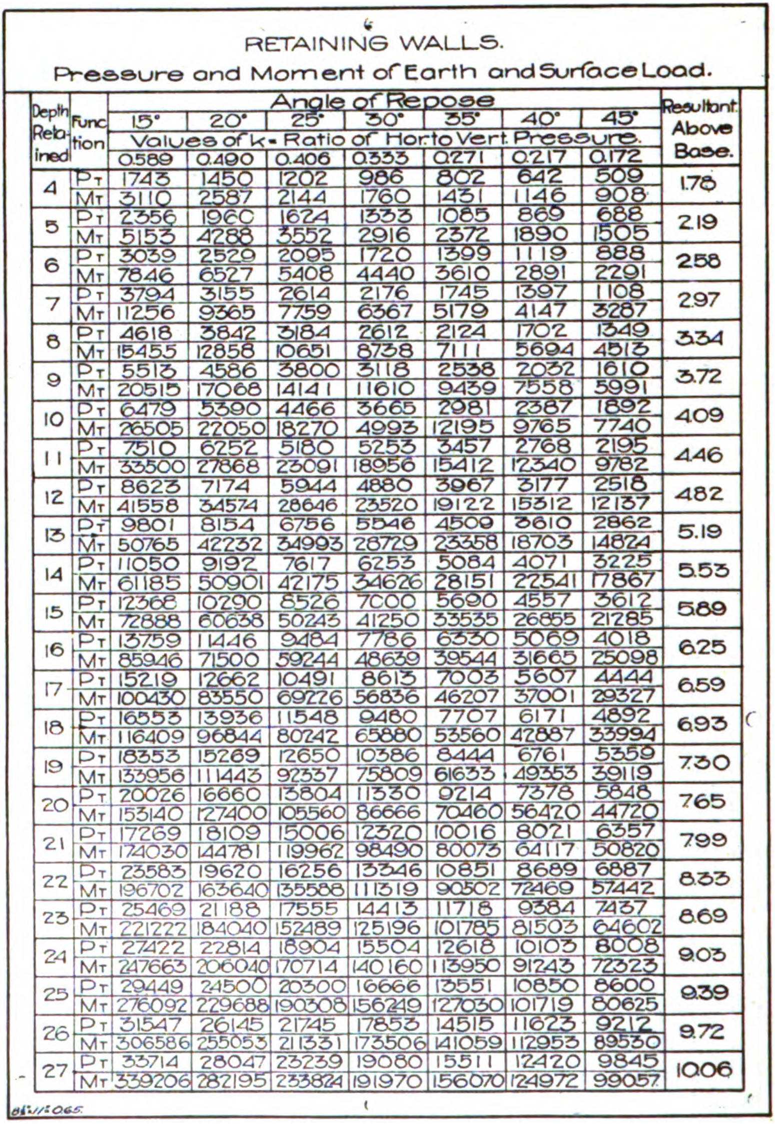


RETAINING WALLS.

Pressure and Moment of Surface Load of 500 lbs. per Sq. Ft.

Depth Retained	Function	Angle of Repose 15°	20°	25°	30°	35°	40	45°	Resultant Above Base.
		Values of k = Ratio of Hor. to Vert. Pressure.							
		0.589	0.490	0.406	0.333	0.271	0.217	0.172	
4	Ps	1178	980	812	666	542	434	344	2.00
	Ms	2356	1960	1624	1333	1084	868	688	
5	Ps	1472	1225	1015	833	678	543	430	2.50
	Ms	3681	3063	2537	2083	1694	1356	1075	
6	Ps	1767	1470	1218	1000	813	651	516	3.00
	Ms	5301	4410	3654	3000	2439	1953	1548	
7	Ps	2062	1715	1421	1166	948	759	602	3.50
	Ms	7216	6003	4974	4083	3320	2658	2107	
8	Ps	2356	1960	1624	1333	1084	868	688	4.00
	Ms	9424	7840	6496	5328	4336	3472	2752	
9	Ps	2651	2205	1827	1500	1220	977	774	4.50
	Ms	11927	9924	8222	6750	5488	4394	3483	
10	Ps	2945	2450	2030	1665	1355	1085	860	5.00
	Ms	14725	12250	10150	8333	6775	5425	4300	
11	Ps	3239	2695	2233	1833	1490	1193	946	5.50
	Ms	17820	14823	12282	10083	8198	6564	5203	
12	Ps	3534	2940	2436	2000	1626	1302	1032	6.00
	Ms	21204	17640	14616	12000	9756	7812	6192	
13	Ps	3828	3185	2639	2166	1761	1410	1118	6.50
	Ms	24885	20702	17153	14083	11450	9168	7267	
14	Ps	4123	3430	2842	2333	1897	1519	1204	7.00
	Ms	28861	24010	19894	16333	13279	10633	8428	
15	Ps	4417	3675	3045	2500	2032	1627	1290	7.50
	Ms	33130	27563	22838	18750	15243	12207	9675	
16	Ps	4712	3920	3248	2666	2168	1736	1376	8.00
	Ms	37696	31360	25984	21333	17344	13888	11008	
17	Ps	5006	4165	3451	2833	2304	1844	1462	8.50
	Ms	42555	35403	29333	24083	19580	15678	12427	
18	Ps	5103	4410	3654	3000	2439	1953	1548	9.00
	Ms	47709	39690	32886	27000	21951	17577	13932	
19	Ps	5595	4655	3857	3166	2574	2061	1634	9.50
	Ms	53157	44223	36642	30083	24458	19585	15524	
20	Ps	5890	4900	4060	3330	2710	2170	1720	10.00
	Ms	58900	49000	40600	33333	27100	21700	17200	
21	Ps	1684	5145	4263	3500	2845	2278	1806	10.50
	Ms	64936	54023	44762	36750	29877	23924	18963	
22	Ps	6479	5390	4466	3666	2981	2387	1892	11.00
	Ms	71269	59290	49126	40333	32790	26257	20812	
23	Ps	6774	5635	4669	3833	3116	2496	1978	11.50
	Ms	77895	64803	53693	44083	35840	28698	22747	
24	Ps	7066	5880	4872	4000	3252	2604	2064	12.00
	Ms	84816	70560	58464	48000	39024	31248	24768	
25	Ps	7362	6125	5075	4166	3388	2713	2150	12.50
	Ms	92030	76563	63438	52083	42343	33906	26875	
26	Ps	7657	6370	5278	4333	3523	2821	2236	13.00
	Ms	99541	82810	68614	56333	45799	36673	29068	
27	Ps	7951	6615	5481	4500	3638	2929	2322	13.50
	Ms	107340	89302	73994	60750	49389	39548	31347	

Table 3



RETAINING WALLS.

Pressure and Moment of Earth and Surface Load.

Depth Retained	Function	Angle of Repose 15°	20°	25°	30°	35°	40°	45°	Resultant Above Base.
		Values of k = Ratio of Hor. to Vert. Pressure.							
		0.589	0.490	0.406	0.333	0.271	0.217	0.172	
4	P_T	1743	1450	1202	986	802	642	509	1.78
	M_T	3110	2587	2144	1760	1431	1146	908	
5	P_T	2356	1960	1624	1333	1085	869	688	2.19
	M_T	5153	4288	3552	2916	2372	1890	1505	
6	P_T	3039	2529	2095	1720	1399	1119	888	2.58
	M_T	7846	6527	5408	4440	3610	2891	2291	
7	P_T	3794	3155	2614	2176	1745	1397	1108	2.97
	M_T	11256	9365	7759	6367	5179	4147	3287	
8	P_T	4618	3842	3184	2612	2124	1702	1349	3.34
	M_T	15455	12858	10651	8738	7111	5694	4513	
9	P_T	5513	4586	3800	3118	2538	2032	1610	3.72
	M_T	20515	17068	14141	11610	9439	7558	5991	
10	P_T	6479	5390	4466	3665	2981	2387	1892	4.09
	M_T	26505	22050	18270	4993	12195	9765	7740	
11	P_T	7510	6252	5180	5253	3457	2768	2195	4.46
	M_T	33500	27868	23091	18956	15412	12340	9782	
12	P_T	8623	7174	5944	4880	3967	3177	2518	4.82
	M_T	41558	34574	28646	23520	19122	15312	12137	
13	P_T	9801	8154	6756	5546	4509	3610	2862	5.19
	M_T	50765	42232	34993	28729	23358	18703	14824	
14	P_T	11050	9192	7617	6253	5084	4071	3225	5.53
	M_T	61185	50901	42175	34626	28151	22541	17867	
15	P_T	12368	10290	8526	7000	5690	4557	3612	5.89
	M_T	72888	60638	50243	41250	33535	26855	21285	
16	P_T	13759	11446	9484	7786	6330	5069	4018	6.25
	M_T	85946	71500	59244	48639	39544	31665	25098	
17	P_T	15219	12662	10491	8613	7003	5607	4444	6.59
	M_T	100430	83550	69226	56836	46207	37001	29327	
18	P_T	16553	13936	11548	9480	7707	6171	4892	6.93
	M_T	116409	96844	80242	65880	53560	42887	33994	
19	P_T	18353	15269	12650	10386	8444	6761	5359	7.30
	M_T	133956	111443	92337	75809	61633	49353	39119	
20	P_T	20026	16660	13804	11330	9214	7378	5848	7.65
	M_T	153140	127400	105560	86666	70460	56420	44720	
21	P_T	17269	18109	15006	12320	10016	8021	6357	7.99
	M_T	174030	144781	119962	98490	80073	64117	50820	
22	P_T	23583	19620	16256	13346	10851	8689	6887	8.33
	M_T	196702	163640	135588	111319	90502	72469	57442	
23	P_T	25469	21188	17555	14413	11718	9384	7437	8.69
	M_T	221222	184040	152489	125196	101785	81503	64602	
24	P_T	27422	22814	18904	15504	12618	10103	8008	9.03
	M_T	247663	206040	170714	140160	113950	91243	72323	
25	P_T	29449	24500	20300	16666	13551	10850	8600	9.39
	M_T	276092	229688	190308	156249	127030	101719	80625	
26	P_T	31547	26145	21745	17853	14515	11623	9212	9.72
	M_T	306586	255053	211331	173506	141059	112953	89530	
27	P_T	33714	28047	23239	19080	15511	12420	9845	10.06
	M_T	339206	282195	233824	191970	156070	124972	99057	

Table 4

of 30° material weighing 100 lb. per cu. ft. is to be retained by a wall resting on similar material at a depth of 4 ft. below the surface at the toe, and that the surface load on the embankment may be 200 lb. per sq. ft.

From Table 1, Opposite 4 ft. and 30° take 427
Multiply by 20/120=................ 71
From Table 2, Opposite 22 ft. and 30° take 70,986
Multiply by 100/120=................59,000
From Table 3, Opposite 22 ft and 30° take 40,333
Multiply by 200/500=................16,133
75,204

In Table 4 under 30° and opposite 19 ft., the nearest equivalent overturning moment is found to be 75,809 ft. lb.

A wall 19 ft. high may then be assumed and used in Figs. 5 or 6 to determine the approximate base required.

For general use, I suggest that Figures similar to 5 and 6, for material weighing 100 lb. per cu. ft., and no surface load or surcharge be used in connection with tables similar to 1 and 2 upon the same basis; and that a table similar to Table 3, but for a surface load of 1,000 lb. per sq. ft. would be most convenient for conversion to any surface load desired. To select an approximate base for a surface loaded embankment wall take the sum of M and M_s and select a higher wall of equivalent moment to use in tables mentioned prepared for material weighing 100 lb. per cu. ft. and no surface load.

DISCUSSION.

The Author: Referring to statements by Rankine, quoted on the sixth page of the paper, my understanding of what he proposed to do was nothing more than passing a plane through a body, determining the weight above that plane and the friction on the plane, but Rankine's theory of conjugate pressures was used in solving the problem. The result, as will be shown later, is the same in some special cases, and in other cases where it seems to fail I believe the explanation to be as follows: The theories of Rankine have been discredited because they failed when an inclined instead of horizontal fill was placed against a wall. If you will read his theory of conjugate stresses as applied to earth pressure, and the arguments on which it is based, you will find it is based on unlimited planes, ***not on limited planes.*** For that reason different results are obtained by his and other methods. If the pressures from limited planes were used in calculation, the result would come out correct.

W. C. Armstrong, M. W. S. E.: The paper is a very interesting one to me and I have no doubt it is to all of those who have ever been interested in retaining walls. I think it is always profitable to discuss these problems from a mathematical standpoint, more particularly, perhaps, in determining the laws governing the design rather than in determining actual working formulae. I have not followed the mathematical work of the author closely enough to attempt to discuss it except in a very general way, and therefore will not attempt to make any criticisms on the working out of this problem. There are some things in which I would perhaps not agree with the author. In fact, if we were all agreed on the subject we would not have anything to discuss.

The author's statement that designers of retaining walls have followed the easy rule-of-thumb, not making any calculations on the exact pressure under the toe and heel, I think is hardly true in the present day. It may be that in the past a great many retaining walls were designed in that way, but I think at the present time most engineers design their walls according to some formula or some rule. You may call it a thumb rule, if you choose, but in most cases, if it is a thumb rule, it is derived from more exact mathematical calculations. In work which I have had charge of, we never have designed walls in which we did not calculate the pressure upon the base both at the toe and at the heel. We generally have disregarded the question of whether the resultant fell within the middle third, because we have worked on a different method of calculation; but we have always calculated our pressures—we have never guessed at them—and I think that will be found generally true of most of the walls that are designed and built at the present time.

I doubt whether any improvement would be made in the actual design of walls if we used more exact formulae or whether any better results would be obtained than are obtained now with the shorter methods of calculation. I would not want to discourage the use of mathematics and I think it is an excellent thing for an engineer to keep brushed up in his mathematics. At the same time, I would want to add the additional injunction that he season his mathematical porridge with a good amount of common sense. The two always go hand in hand and a structure designed entirely upon mathematical deductions often proves to be weak in many essential features.

There is one point in the paper that is not very clear to my mind and that is just what the author means by the factor of safety or how he would apply it. The factor of safety is ordinarily applied in engineering design by using a unit of stress or pressure which will be well within the safe limit. If we will assume, for instance, that with a pressure of 4,000 lb. per sq. ft. on the underlying material, the material is just at the point of yielding or flowing, then, if we take half that amount, or 2,000 lb. per sq. ft., as the allowable unit pressure, we shall have a factor of safety of two. Now, why is it not just as well to use a unit pressure that will be safe rather than to introduce this factor of safety as an additional term into the calculation?

The author refers to the factor of safety usually used in metallic structures as being from four to five. We do not use a factor of from four to five. It is generally assumed in steel construction that we use a factor of about two, although a steel structure designed according to present practice would probably not fail absolutely if stressed from three to five times the amount for which it is designed, although objectionable deformation might take place.

Referring to Equation 3, which is a well-known formula for pressures, it is a very easy matter to reduce this to a simple form and make it readily applicable. Assuming the value of the angle of repose at 1½ horizontal to 1 vertical, corresponding to an angle of 33° and 40′, and reducing we get

$$P = 0.143\ wh^2.$$

If we assume earth to weigh 100 lb. per cu. ft., which is the weight of ordinary filling, this would become

$$P = 14.3h^2.$$

This is the form of equation I have used in designing for a good many years, except instead of the coefficient 14.3 I have used 15, making the formula

$$P = 15h^2$$

which is more simple and gives a little additional safety.

If we wish to assume earth filling at 120 lb. per cu. ft., we simply write

$$P = 18h^2.$$

I see no reason for not using such simple methods in actual calculation, rather than the complicated formulae and diagrams that frequently we have proposed. It makes a simple method of determining the external pressure. From this we can readily determine the moment of the pressure or the overturning moment. Calculating the weight of the wall, we can readily determine its moment around the center of the base, which is the moment of resistance. The combination of the two will give the resultant moment, and with the resultant moment at the base it is a very easy matter to calculate the actual pressure at the heel and toe.

There is one other point that I wish to mention: No matter how accurately and carefully formulae for retaining walls are worked out, we have to apply them to a construction in which the data will always be uncertain. I do not know of any engineering structure to which exact mathematics in the actual design is less applicable than to retaining walls. It is practically impossible to determine the angle of repose. It is equally difficult to determine the angle of internal friction; and to assume that the angle of internal friction is equal to the angle of repose may lead to erroneous results, although I do not understand that the author advocates this in all cases.

The angle of internal friction of the material we have underlying the city of Chicago is a considerable quantity. How much nobody knows, nor will they ever know. The angle of repose may be anything from zero to 90°, and it seems to me that the best way to arrive at the proper solution of this problem is to assume a granular material of proper weight, based upon the ordinary theories, which are nearly enough correct for practice, and design the wall accordingly. The most important thing to be determined is the pressure which the underlying material will stand. That is something that is subject to experiment and can be determined with a reasonable degree of accuracy, but the angle of repose and the angle of internal friction are things that cannot be accurately determined.

O. P. Chamberlain, M. W. S. E.: In years gone by I have built a good many retaining walls. There is one feature that Mr. Armstrong has mentioned which I think is not carefully taken into consideration, and that is the character of material upon which the wall is built. I think the engineer makes assumptions as to his foundations very often where he could really determine the character of the material. It is essential that the character of the wall and the width of the wall at the base should be considered in accordance with the surrounding material and upon which it is constructed. If it is a very long retaining wall there may be a considerable variation in the character of the foundation within a rather short distance. While that can be determined and should be determined, it has been, I think, common practice among a great many of the engineers to design the wall for what is considered about the average pressure which can be allowed on the bearing material and put the wall through accordingly. I have not studied this paper carefully enough to go into the mathematics of the question, but my own practice has been to handle the matter by such simple formulae as Mr. Armstrong has suggested.

I. F. Stern, M. W. S. E.: I am glad the chairman called for remarks from the previous speakers, because they said some of the things I might have said, and the author said one or two things about which I might have made some remarks.

I wish I could say, as Mr. Armstrong said, that there is one point in the paper which I cannot understand. There is not only one point but unfortunately several others on which I am not clear. It reminds me of a friend of mine who was going to a doctor for treatment of some disease. One day he said, "Do you know, doctor, there is one point in your treatment that I cannot quite understand." The doctor said, "That is strange. You are very modest. I have spent my entire life, and I am sixty, working on that proposition, and now you, who are but twenty and have never studied medicine, find there is one point about this treatment which you do not understand.."

I have built quite a few retaining walls in my time, and I remember that in 1901, in some of the earliest work I did, which was under Mr. Armstrong's direction, we went into the proposition, or thought we did, quite thoroughly. I have since come to the conclusion that if I ever know as much about it as I thought I knew then, I shall be satisfied.

In some ways the design of a retaining wall is like the design of machinery for electrical operation. The motors are put in to do a certain duty. You have a certain motor, say 50 h. p., and you design your shafting and everything else for that. You may have a starting torque of 200 h. p., and what are you going to do, design your machinery for the 200 h. p.? A great many of the designers of machinery are now making the shafting and everything else that connects to the motor just about as large as they can get into the machinery house. That is a safe way, but, as the speaker pointed out, it is not the economical way to make your retaining walls as large as you can possibly get them.

I do not want to be quoted as stating that I do not believe in mathematical analysis, but I want to say what I said at a recent meeting at which the subject of retaining walls was discussed by one of our members. As I remember it, he proved that the pressure on a wall from a level fill was the same as that from a surcharged fill at the angle of repose. We had time to go into that paper sometime before it was presented, and we agreed with the speaker that the pressure at the very top of the wall was absolutely the same whether it was a level fill or a surcharged fill, but that was the only point on the wall where you would get the same pressure from the two conditions. That is the trouble with mathematical analysis unless it is backed by one of the things that the author deprecates. He says something about lazy folks taking the most pains, and refers to a designer who was so lazy an engineer that he "simply applied the practical knowledge acquired by long experience to dictate the lines of the structure. There are such engineers."

I said at that meeting that I thought it a very good thing that the passing on the design of structures in this country is usually in the hands of a man of seasoned experience, so that he can be classified as a visual engineer. I want to adhere to that statement. If you design a structure mathematically and you look at it and it does not look right to you, figure it over again and you will generally find where you made the mistake. If you depend upon mathematics absolutely, you may go over your figures two or three times and not find your error; but if you are a good visual engineer (and the men who build structures must be that, they must develop that sixth sense, as it were), why, then, you know you have made a mistake. Those of us in charge of designing cannot go through all the mathematics in the design of a large structure, in the design of a bridge, or possibly in the complete design of a retaining wall; there are too many other things to do. We must be able to know instinctively, when looking at the drawing, whether it is right or not, because of our preliminary training; and if necessary, why, then, we can figure it to show that it is wrong. I have a good deal of sympathy and a good deal of feeling for the man who looks at a drawing and says, "That is not right. It doesn't look right to me." If that man has had the proper preliminary training he generally knows what he is talking about and that sort of knowledge is generally superior to the knowledge of his subordinates and to the results which they have attained by pure mathematical analysis.

With regard to the basis of computations, in practically all the designs of retaining walls that I have had under my direction, we have used Rankine's formula as amplified and brought down to a working basis by Professor Charles E. Greene, formerly of the University of Michigan, whose book on Graphics is, I believe, the best ever produced in this country. If you go through that demonstration where you have an absolutely graphical analysis and find it on proper assumptions for the angle of repose of the material, you can see what you are getting to and you can tell, when you get through, whether the proposition looks right or not. If it does not look right you can go through a few lines of the construction and discover where you made your error and then go back and do it right.

Ernest McCullough, M. W. S. E.: I am very much in accord with most of the older engineers in the wish to use simple expressions for obtaining the pressure or some measure of the forces that would tend to overturn a wall. But at present we are facing new conditions.

I have had considerable experience in designing and building retaining walls, and used for years a formula $P = 16h^2$, based on that of Coulomb's theory of the wedge of least resistance instead of $14h^2$, or $15h^2$, which Mr. Armstrong said he used. Fig. 4 amounts to about that, taking the usual condition of Φ. The reasons I think were brought out pretty clearly three or four years ago in a discussion in this room on retaining walls.

When Sir Benjamin Baker's paper, which is so often referred to, was presented before the Institution of Civil Engineers, he was engaged in putting in about forty miles, I believe, of underground railways (or tubes as Englishmen term a subway) through the deep clay underlying the city of London, and the only walls designed in those days were of the gravity type. His paper seemed to be nearly the last word in English on retaining walls, except for a few monographs by mathematically inclined professors, until recently the introduction of reinforced concrete walls has compelled engineers to sit up and take notice. Our chief reliance for some time must be on mathematics until a new fund of information is acquired, based on the conditions presenting themselves.

The clay on which Chicago is built is quite similar, from all descriptions I can get hold of, to the clay underlying London. The conditions under which the subways are to be built are very similar to the conditions under which the London tubes are built, which called forth the famous discussions of engineers in the early '70s. But we have different loadings from the ones they had in those days, with a more intense street traffic. This paper by Mr. Pearl is the first contribution Chicago will make to supplement the data obtained in London.

At present the older engineers can design a wall which will look strong, their experience and the experience of many generations of men before them being the only guide. A reinforced concrete wall can be designed in many shapes and it needs more than a glance from an experienced eye to tell that it is safe.

C. R. Dart, M. W. S. E.: I am inclined to agree with Mr. McCullough. We have new problems now in reinforced concrete which require new experience. I think mathematics is going to enter into the question more than has been the case in the past.

B. E. Grant, M. W. S. E.: This paper reminds me in a way, of a remark of a friend of mine who is not an engineer, but who has come in contact with many engineers. He says an engineer sits down and figures—makes a whole lot of figures—and when he gets through he guesses at it. Now, that is partly true, I think, of retaining walls. An engineer ordinarily does, I think, when he first designs a retaining wall, make a whole lot of figures and assumes conditions; when he gets through he gradually works down to a simple formula, such as Mr. Armstrong suggests, and, in a way, guesses at it. Of course, that is not an unskilled guess. It is a guess based on past experience, and that remark is absolutely right.

The author refers, on the second page of his paper, to the failure of the large gravity wall on the New York State Barge Canal. The first query that came to my mind, when I read that it failed, was as to how the filling was put in there. A little further along in the paper the author says the fill was dropped. He does not tell us the conditions. He assumes two or three different conditions here and then tells us that the failure could not be due to the dropping. I am not altogether sure about that.

Some years ago, when the Sanitary District of Chicago built several miles of retaining wall, they built one that was supposed to be amply strong. There was a section of several hundred feet of it that fell and surprised not only the contractor but I think surprised the engineers. At that time I think it was considered that the failure of the wall was due to the filling behind it, which was dropped from derricks. That was not a liquid filling; it was solid rock. I think the failure was due very largely to the vibration that was set up; every time a bucket of rock was dropped, a vibration ran along the wall, and it has always been my idea that it was the vibration and shock that caused the failure of the wall.

John F. Hayford, M. W. S. E.: Reference has been made to the failure of a wall on the New York Barge Canal. I remember the description of this wall which appeared in the *Engineering*

News, and also that some of the buckets dropped their loads 40 ft. So it seems to me, in reading this paper, that we ought to put the paragraph reading:

> "The engineering paper in which the failure was recorded attributes the disaster to the dynamic effect of dropping scraper bucket loads of earth in making the fill. As the bucket loads probably weighed less than four tons and consisted of loose earth dropped on loose earth, it is difficult to understand how the four tons moved the 14,000 tons beyond a safe range of elasticity, and more difficult to comprehend how the 'dynamic effect' was prolonged through the period of four hours occupied in moving an average distance of about 12 ft."

alongside of the one to be found further on in the paper, as follows:

> "The value of the coefficient of internal friction, as has been shown, is the predominating argument in all methods of computation and should be determined with care and for the most unfavorable variations of saturation, shock, and vibration that may be anticipated in any case."

Now, I submit that if the author of the paper will start again with his computations, and with his mathematics, and take the extremely unfavorable conditions of saturation, shock, and vibration in the case of that Barge Canal, he will succeed in proving that the wall was mathematically wise when it fell over.

I suppose because I happen to be a professor I ought to put up a defense, or some kind of a remark, when a "mathematically inclined professor" is referred to. Now, it seems to me that we would come down to a bearing on our matter if we looked for a moment at what mathematics can do in connection with a problem like this,—what mathematics can do in any case. Mathematics simply furnishes one a means for getting at the correct logical conclusion from a given set of facts or a given set of assumptions. I submit that is all that mathematics does for you. It gets from certain facts or certain assumptions the proper logical conclusions, provided your facts or assumptions are quantitative. Now, if your assumed facts are not facts or if your assumptions are not valid, then, regardless of whether your mathematics is refined or rough, the errors due to the errors in your assumed facts or in your assumptions will be in your final result in any case. That is, it make no difference how good or how poor is your mathematics, the errors in the result due to the errors in your assumptions or assumed facts are going to be there in any case.

I submit that this case of retaining walls is pre-eminently one in which the final errors are due largely, in the average case, to the errors in the assumptions or in the assumed facts.

Take this case of the material under Chicago. It is not only true it is difficult to determine the angle of internal friction, but I submit it is pretty certainly true that the angle of internal friction in the material under Chicago is not the same in different parts of the material, nor anywhere near the same. Moreover, it is not the same in any one spot at different times. According to the surrounding conditions for the spot, it changes from time to time according to what you have done in the loading up or unloading of the surface near there, and in drawing the level of the ground water down at different times. There are probably other influencing factors.

It seems to me that in connection with retaining walls one may say, as a general rule, that rough mathematical methods are the ones to use; because if you use quick methods in your mathematical processes, in your computations, you will have more energy left to study your assumed facts and your assumptions. That is where study is needed in this matter of retaining walls; not in the mathematics primarily but in the assumptions back of the mathematics.

E. E. R. Tratman, M. W. S. E.: With regard to the failure of a wall on the Barge Canal, a published account of this (in *Engineering News,* February 20, 1912), shows that when the back filling was commenced there was about 5 ft. of water in the space between the heel of the wall and the slope of the excavation. The result was that the bottom 10 ft. of the fill was a quaking mass which would not support a man. Above that the fill was moist but a man could walk upon it.

The fill was being made with a 3½-yd. scraper bucket, which dropped its load from heights of 10 to 40 ft., so that there was a continuous succession of impact loads coming upon this quaking mass and against the wall. Such a process would cause very severe shocks and vibration, which the wall was never intended to sustain, and would not have sustained under proper methods of construction. In addition, it appears that the filling was not level, but the scraper was kept in one place until it had done all the filling within its reach, so that in some places the fill was 12 ft. higher than at others. Furthermore, it is stated that the pressure and vibration tended to force the water out under the base of the wall, thus lubricating its foundation.

The combination of impact pressure, irregular load, shock, vibration and lubricated base would materially affect the stability of a wall of ample strength for normal conditions. It would be most uneconomical, and in fact impracticable, to design a wall or other structure to meet all possible conditions of stress due to improper methods of construction.

In the published description of the accident it is stated that the wall was rebuilt on practically the original section, the engineers deciding that the design provided a wall that was perfectly safe as a static structure. It is fair to assume that after the failure the design was carefully studied and was found to be of ample strength for any conditions that could properly be considered as factors in the design. But no doubt care was taken to see that this time the construction, and especially the back filling, was done in proper manner.

As to giving the names of persons responsible in the case of failures and accidents, an examination of reports of such accidents will show that this is done in a great majority of cases.

It seems to me that Dr. Hayford's caution as to the limitations of the value of mathematics states a case of fundamental importance. There may be too great reliance on mathematics as well as on rule-of-thumb for purposes of design. If the assumptions which form the basis of a mathematical calculation are incorrect, the mathematical structure will fail on account of poor foundation, no matter to what degree of higher mathematics it is carried. Mathematics simply constitutes a tool for the engineer's use, and it must be used properly and intelligently, the same as any other tool.

S. T. Corey, M. W. S. E.: Would it be allowable to figure on the abutting power of a bridge to hold up an abutment?

The Author: Certainly it would be allowable. One of the noted bridges in the world is built across the Tiber, at Rome. It is a reinforced concrete arch bridge of 328 ft. clear span with a rise of one-tenth the span, and is founded on a silty bottom.

W. S. Lacher, ASSOC. W. S. E.: I have seen a number of highway bridges in which the condition of the bottom chords made it very plain that they were serving, to a considerable extent, to hold up the abutments. In that same connection, a member of the engineering staff of a certain State Highway Commission once put to me this proposition: How much should an engineer make his client pay for insurance on his own reputation?—that is, on the engineer's reputation? The subject came up in connection with a discussion of retaining walls. In the introduction of structures designed and built under the supervision of a State Highway Commission there is some competition with a very inferior class of engineering. In connection with retaining walls, engineers of this type in an effort to build bridges without state supervision used to ridicule the use of retaining walls with a base of even one-third the height. They had been in the habit of using about one-sixth, and that is what brought up this proposition. If a great many walls built of that section, or with an equivalent factor of safety, stand up, why should not all of them be built that way? If a few of them fall down, well and good. The total number of walls have been built with a very small percentage of failures. Therefore, how much can a man afford to charge his client in the way of extra expense for a wall that he is sure will not fall down? Whereas, if the walls were not so strong perhaps a few would fall down, but the total expense distributed over all of his clients would be very small. This is submitted as an abstract proposition, not as a recommendation.

F. G. Vent, M. W. S. E.: Mr. Armstrong brought up the question of whether the resultant fell outside of the middle third. If the resultant was outside of the middle third, we would have theoretically an uplift in the back of the wall. As a matter of fact, we know many walls designed according to the best formulae will stand if the resultant passes outside of the middle third. It goes to show that our formulae are on the safe side, and if we want to skin them down, why not make a new formula? If we know a wall is going to stand with a certain base, why not reduce the whole thing to an equivalent hydrostatic formula of our own, and use it in our designing? If we know what kind of soil we are putting our wall on, and whether or not it is going to stand up, and we feel safe in saying it is going to stand up with a certain base, we can make our own formula, a formula much less than the one we would use if we had to let our resultant go outside of the middle third.

Mr. Stern: Mr. Armstrong is not here and as I have done a good deal of work with him, I will endeavor to clear up what he said, if I may.

Mr. Armstrong said he generally disregarded the question of whether the resultant fell within the middle third. He said: "We figure the pressure on the front and pressure on the back." My understanding from that remark was that one could then, of course, immediately see that if he had any pressure on the back and pressure on the front the resultant had to go inside of the middle third, because otherwise he would get a negative force at one end.

Mr. McCullough: As to the middle third proposition: This is merely a way of stating that if the pressure on the front edge is not to exceed twice the average, with no tension on the back edge, the resultant of the pressure must be kept within the middle third.

I do not think Mr. Armstrong said he would willingly let the pressure get outside of the middle third, because he qualified his remarks by saying, as Mr. Stern said, that he figured the pressure on the front and back, but sometimes a little justified risk could be assumed on the insurance proposition. There had to be so many miles of wall built and it cost so many dollars per mile, and they had just so many dollars to do it with. The thing was to get the greatest amount of wall with the dollars they had, if the soil seemed to be right to permit it. But he said expressly that he used the formula $P = 14h^2$, which meant that he assumed a fluid having a weight of about 30 lb. per cu. ft., thus reducing the actual earth pressure to that of an equivalent fluid. Therefore, if the pressure was computed, the middle third rule could be ignored.

Mr. Vent: I think that the risk has been taken by engineers of passing the resultant somewhat outside of the middle third because they knew that the wall was going to stand up.

The Author: In regard to the abutting power of earth and the safety of using it, mentioned by Mr. Corey, many suspension bridges in this and other countries have been built where they have relied on the abutting power of earth for their anchorage. In fact, I had occasion some years ago to take down a suspension bridge built by Alfred P. Boller that required the abutting power of earth for its stability. Arches have also been built upon earth foundations and in such manner that the abutting resistance of the material was necessary to stability; in fact I consider it quite as safe practice as the construction of retaining walls on earth foundations.

In regard to the $15h^2$ rule. All earth does not look alike to me, neither the material itself nor the contours of its surface. It does not look the same to me when it is inclined either upward or downward away from a wall. The conclusion that some consider it practically alike when the surface is level must follow from the use of formula $15h^2$.

In regard to the factor of safety, I advocate the determination of the safe pressure at the toe of the wall from the depths of the toe and the character of the material in the manner indicated by equations and given in tables for depths up to 8 ft. in my paper.

The manner of treating the pressure from earth as an equivalent of fluid of less weight will lead to difficulty when an attempt is made to provide for a surcharged wall or a superimposed load. It will also lead to trouble when figuring foundations. The method proposed is believed to be general, and I request some of the gentlemen present to show in what respect it is not general. The sole assumption is that there is a surface somewhere in the body, whether it is a plane or an irregular surface, and there is friction on the surface proportional to the weight of material above it. That is all the assumption that enters into the problem, and the method may be applied to a wall holding a fill of any shape or surcharge whatever.

Mr. Vent: May we hear from the author as to the resultant falling outside of the middle third?

The Author: The resultant does not fall outside of the middle third until negative pressure appears to be necessary at the heel of the wall to insure stability.

Mr. Vent: Is it allowable?

The Author: It is allowable in some cases, as on a rock foundation.

In regard to Sir Benjamin Baker's experience, experiments and empirical formulae for walls; if Mr. McCullough will look the matter up I believe he will find that at the time the rules were prepared they were building walls with buttresses, with counterforts, with horizontal arches and various other designs for relieving or counterbalancing lateral pressures.

I recall some experiments in which the friction upon the sides of counterforts was considered in determining the stability. In a recent English publication I found instructions in designing walls with counterforts in which directions were given to figure the wall as having a base equal to the *average* thickness. The absurdity of such a proposition, to anyone who has occasion to use the moment of inertia in computing stresses, will be apparent.

Mr. McCullough: O, yes, that was mentioned in the paper.

The Author: I was under the impression that they had other than plain walls in those days.

Mr. McCullough: I think the object of that paper was to bring out the question as to whether, with the classes of walls they had at the time, it was worth while to bother with formulae. Very few structures with relieving arches, abutments, buttresses, or anything of that kind, were as satisfactory as the designers hoped they would be.

The Author: The wall that stands up for a time is not always a safe guide. Many of them have stood up for ten years and then gone wrong. This is true of bridges, too,—bridges that apparently had a safety factor of five. Some of them, like Quebec, did not stand up until completed. I call attention to this simply to illustrate that perhaps it was thought the earth at the bottom of the river was just the same as at any other place.

Mr. Corey: I would ask the author about how he treats live loads behind. The paper does not say anything about that. Suppose you had a track 8 ft. from the wall and Cooper's E-55 loading; how would you treat that condition?

The Author: I would place the superimposed load in its true position on the diagram, locate imaginary planes cutting through the load and earth, and proceed with the combined weights in the same manner as for the earth alone.

Mr. Corey: Take Cooper's specifications E-55, for instance; that would be 55,000 lb. driver load.

The Author: I would reduce the driver load to equivalent uniform load over the area determined by the wheel base and length of ties.

Mr. Corey: Some engineers assume the driver loads and some only use the box-car loads.

The Author: I believe that if a designer figures his wall as has been the custom for the past 50 or 60 years, he would be liable to get into trouble, but if he uses a safety factor of two or three in the design he would be safe in taking a uniform load.

Mr. Reichmann: There would be a lateral distribution anyway, wouldn't there, Mr. Pearl?

The Author: Yes, but I do not think it safe to depend on that. I believe the most reliable proposition is to take a plane through the superimposed load, figure the weight above the plane, and allow for the friction. Take other planes at intervals of five or ten degrees. Treat the resultant weight as shown in Fig. 2, determine the resultant pressures, and select the maximum.

Mr. Corey:. The object I had in asking that question is that apparently h^2 would only take care of that friction.

The Author: The surcharge could be treated just as though there was no other weight on the plane, if desired. You can treat the two weights separately or combine them in an equation and differentiate to determine the maximum.

Mr. Vent: What I desired to bring out in my previous remarks was that the engineer must combine his professional experience and common-sense judgment in the interpretation of the retaining wall literature at his disposal in order to obtain the best and most economical wall for his particular place. With all the formulae at his disposal, he may find it to his advantage to let the resultant pass slightly beyond the middle third of the base, even though the wall is not on a rock foundation. And if he skins the wall down from what would be required by these formulae, he must do so only on the absolute knowledge corroborated by his extended experience, that the soil conditions will warrant it. This does not mean that the real resultant is going to pass beyond the middle third of the base, but it shows that the engineer is warranted in making a new formula for his personal notebook, which will give a smaller back thrust upon his wall, and which will keep the resultant in the middle third of the base. He can make his own formula, giving an equivalent hydrostatic back pressure *P*, which will take care of a back fill with no surcharge, and in case of a surcharged back fill, the surcharge can be equated to a floating load, which would simply mean that the equivalent hydrostatic level would be raised by a proper displacement due to the floating load, as though it were confined in a proper sized tank, and a table made to give the equivalent increase in hydrostatic head, due to surcharge, would take care of surcharges in a simple manner.

As the ratio of thrust to vertical loads changes somewhat in the different heights of abutments for the same soil, it will readily be seen that the angle of inclination of the resultant through the base will change correspondingly. This angle must, of course, be kept light enough to avoid any forward sliding of the abutment upon the base due to too great a proportion of back horizontal thrust to vertical weight. To the overlooking of this point in the design of abutments, we may attribute the cause of so many old abutments sliding forward, and possibly leaning, due to sliding over grillage on piles, and changing the position of the center of gravity of the abutment in relation to the center of gravity of the piles.

I do not wish to convey the impression that a retaining wall would necessarily be skinned down. It will, of course, be appreciated that we must consider the word "skin" in an algebraic sense, and that the engineer may desire to skin the wall in a negative fashion in certain locations, which would mean an increase rather than a decrease in the base.

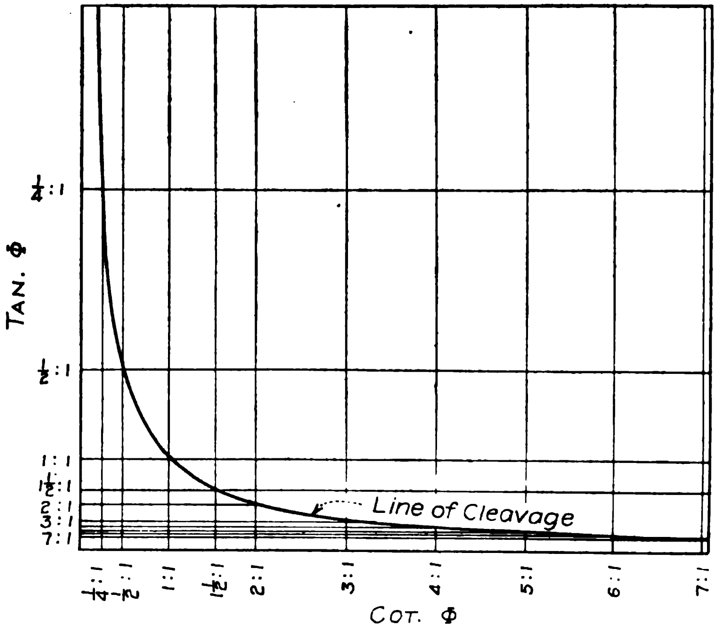
Of course, we have assumed that we have designed a wall by one of the "good" formulae found in the retaining wall literature, and due to our soil conditions we desire to let the resultant pass beyond the middle third (according to said "good" formulae), which amounts to "skinning" said wall according to said good formula. As I said before, we know that said "skinned" wall will have a resultant which will lie within the middle third of the base. We most certainly will not need a formula for said skinned wall, because we happen to know what we want without the good old formula. Why not, then, "make a new formula" which will show the resultant passing at the middle third of said skinned wall and put it away in our notebook for future use in a possible future case of the same soil conditions?

The writer has in mind certain soil conditions which he observed in Seattle, Washington, and other conditions in territory adjacent to rivers with quicksand bottoms, which he believes will defy the analysis of any of our "good" old formulae. I say this with all due respect to all the honest and valuable effort which has been put forth upon the subject of retaining walls by so many of our able engineers. Their works are very valuable and we thank them all, but at the same time I believe the engineer's personal notebook will in time prove to be one of his best assets.

F. W. Green, M. W. S. E. (by letter): This paper is a valuable addition to the literature on the subject of retaining walls, and the author is to be congratulated upon its originality and thoroughness, It is a subject which has often stimulated enthusiasm for mathematical investigation, and which has been quite thoroughly exploited. As in many other engineering works, the difficulty lies in the endeavor to adapt the theoretical assumptions to the concrete example. The element of judgment is, perhaps, the ruling factor, and a cautious discrimination is essential as to the relative requirements of safety from failure on the one hand and economy on the other. In any doubtful case, or work of magnitude, the writer would advocate consultation with experienced and competent authority.

As pointed out by the author, the angle of repose and the angle of internal friction are not always identical. The writer would add that the angle of internal friction cannot safely be assumed to be a constant quantity at all times, especially in the case of plastic materials. In one instance, an alluvial silt stood at a slope of 1.5 to 1 for several months, and then went out to a slope of about 5 to 1, due to the absorption of water. Some materials have a great affinity for water. In one case it is said that a certain clay absorbed 70% of its weight in water, and that while it sustained a live load of over 1,000 lb. per sq. ft. when relatively dry, after absorbing 70% of water it sustained only 46 lb. per sq. ft. In another case a retaining wall for a wharf was designed according to the conventional custom, and backfilling with material excavated from a slip was started, but before it was completed failure by overturning occurred. In such a case, it seems that the only safe course would have been to have designed the wall as a dam with zero for the value of Φ.

The literature on this subject frequently contains references to the peculiar shape of the curve of cleavage when slips occur, as in the case of trenches, and also in embankments. In the writer's opinion this curve is approximately an equilateral hyperbola. The tangent of the angle of friction varies from zero in the case of water to infinity in the case of cubes piled vertically. By plotting the values of tangent Φ against the values of co-tangent Φ, as in the accompanying sketch, this relation is graphically shown. The value of co-tangent Φ, of course, is the slope ratio, horizontal to vertical.



A material which absorbs and retains moisture should be avoided whenever possible as backfilling for retaining walls. When impracticable to avoid its use, too much attention cannot be paid to details essential to drainage; especially is this the case where freezing is liable to occur.

Ira O. Baker, M. W. S. E. (by letter): The following paragraph appears in the paper:

"A writer on masonry construction in this country attacks Rankine's theories and quotes as follows,—'but for want of precise experimental data its practical utility is doubtful,' to indicate that the renowned professor had but little confidence in his own equations. This mutilation of a paragraph covering an entirely separate subject, and using but half of it to discredit the theories applied to a condition devoid of adhesion, was an unfortunate misstep that was retracted by the omission of it in later editions, but without apology."

Doubtless the author refers to Baker's *Masonry Construction*. The author is a little mistaken when he implies that the quoted clause was in a former edition, for the clause referred to is in only the latest edition. The author is also slightly mistaken when he says the writer retracted. In former editions of his book the writer presented an extended statement of the objections to Rankine's theory; but the last edition contains a brief but general criticism of all retaining wall theories which is more severe against Rankine's and other theories than the former editions.

The writer remembers that in preparing his manuscript for the last edition of his book on *Masonry Construction*, he found a memorandum, made some time before, which was substantially like the quotation above; and also remembers that he spent considerable time looking through Professor Rankine's books to locate the quotation; but he was unable to find it until its location was pointed out in the author's paper. It is true that the above quotation is only part of a sentence; and it is also true that the writer applied the quotation in a different way than it was originally used by Professor Rankine. The writer is exceedingly sorry that he made a mistake in using this quotation and will attempt to correct his book at the first opportunity.

The quotation above is half of a paragraph following Professor Rankine's discussion of "Pressure of Earth Against a Vertical Plane," and closes a section entitled "Strength and Stability of Earth Work in General," in Rankine's *Manual of Civil Engineering*. The entire quotation is as follows:

"There is a mathematical theory of the combined action of friction and adhesion in earth; but for want of precise experimental data, its practical utility is doubtful."

Professor Rankine had just completed a discussion of the pressure of earth work in which he had neglected "adhesion." The writer is of the opinion that in his use of the latter half of the above quotation he did no great violence to Rankine's conclusion. For if the practical utility of the theory of earth pressure which takes account of the combined action of friction and cohesion is doubtful because of the lack of precise experimental data, a theory that takes account of only friction and which is not supported by any experimental data is still more doubtful.

Do not let anyone think I am lacking in respect for Professor Rankine. He was a very able and surprisingly versatile man. It is marvelous that one writing at the time he did should have done so well in so many lines. He was truly a pioneer, and deserves the admiration of all modern English-speaking engineers, for they have all greatly profited, either directly or indirectly, by his labors, whether or not they are conscious of it. It is not surprising that there has been great advancement in the art and the science of engineering in the half century since Rankine was attempting to formulate the fundamental principles of engineering practice. Rankine was a thorough-going progressive. It is very interesting to notice how many subjects unfolded and developed in his mind as he wrote. In a later volume upon a related subject he often expands or elaborates a subject already treated in a previous volume; and not infrequently there is evidence of a distinct progression from the earlier to the later parts of the same volume. It was not his custom to restate a matter in its entirety, but only to refer to the former discussion and then give the new idea. Because of this method, some of his presentations are difficult to comprehend; but this method is probably evidence of the limitations under which he worked. If current rumor can be believed, a knowledge of the conditions under which he did his work would greatly enhance the admiration of his ability and persistency.

Let us now consider somewhat briefly the theory of the lateral pressure of earthwork. Of course, to determine the effect of lateral pressure of a mass of earth we must know:

(1) The amount of the pressure;
(2) The point of application of the resultant pressure; and
(3) The direction of this resultant.

(1) There are various formulae that purport to give the maximum thrust of a mass of earth against a retaining wall, all of which are only special cases of a general formula.* Not infrequently the advocates of one formula claim that all others are erroneous. This line of argument has been used in favor of each formula and against all other formulae. Admittedly, all formulae for the amount of the lateral pressure are based upon the following assumptions:

(a) There is no cohesion.
(b) The surface of rupture is a plane.

(c) The internal angle of friction is the same as the external angle of repose. Further, all of the formulae involve mathematical steps of doubtful validity. Universal experience teaches that in all natural soils there is an appreciable cohesion, while in many the cohesion is very considerable. The most super-

---

*Baker's *Masonry Construction,* 10th edition, page 492, eq. 3.

ficial observation will show that when a mass of earth breaks away and slides down, the surface of rupture is not even approximately a plane, as for example, witness the curvature of a caving bank of a river or of a sewer trench. The coefficient of friction in the interior of the mass of earth has no relation to the angle of repose of an exposed surface since the latter is due to the particles of earth rolling down the exposed surface, i. e., to rolling friction, while the coefficient of friction that should be used is that of sliding friction in the interior of the mass. Nobody has ever offered any experimental evidence, or has cited any practical experience, showing the reliability of the formula for the value of the lateral thrust of earth.

(2) All formulae for the pressure of earth assume that the point of application is $\frac{1}{3}h$ from the bottom, h being the height of the bank. The only evidence offered to justify this assumption is that the formula for the amount of pressure contains h^2, and consequently it is assumed that the pressure of earth follows the law of pressure of liquid. However, while one condition of the solution gives the point of application on the back of the wall at $\frac{1}{3}h$ from the bottom, the other conditions of the problem give the point of application on the plane of the rupture at a different point, except for the special case of a vertical wall. Numerous experiments have been made on the lateral pressure of grains and various kinds of seeds in bins, and in no single case does the pressure approximately follow the law of liquid pressure, even though these materials have no cohesion.[*] For example, according to the ordinary theory for earth pressure, the pressure of clean wheat should be $2\frac{1}{3}$ lb. per sq. in. for a head of 8 ft.; while as a matter of fact the actual pressure did not reach $2\frac{1}{3}$ lb. per sq. in. until the head was 30 ft., and what is more the pressure did not increase with a further increase of the head. Experiments with sand give substantially the same results. Several series of experiments have been made upon earth and sand to determine the point of application of the resultant, and in no case was the observed center of pressure of a level bank less than $0.35h$ from the bottom, and in some cases it was as much as $0.50h$. Of course, the ordinary theory of earth pressure requires the point of application to be $0.33h$ from the bottom.

(3) The various formulae for earth pressure differ as to the assumption made concerning the direction of the resultant pressure. Several of the theories make the direction of the resultant pressure depend upon the angle of friction between the earth and the back of the wall; but differ materially as to the details of this assumption, and hence will not be considered further here. Rankine's theory assumes that the resultant is always parallel to the upper surface of the earth; but this does not seem rea-

---

[*] Baker's *Masonry Construction,* 10th edition, p. 500-02.

[†] Ibid, p. 500-01.

sonable, since the direction of the pressure should be the same as that of the motion, which is parallel to the plane of rupture and nearly independent of the surface slope. According to this theory, a wall may be more stable with a surcharge than with a level top surface, because of the difference in direction of the thrust. Dr. H. Müller-Breslau, professor in the Technical High School, Berlin, as one of the results of an elaborate series of experiments using the most scientific and most sensitive apparatus yet devised, distinctly says: "It is especially important to notice that, contrary to the Rankine theory, the slope of the supper surface of the sand has no effect upon the direction of the resultant."

Numerous experiments have been made on the stability of artificial retaining walls, and apparently none agree with the ordinary theory. For example, Sir Benjamin Baker gives* an interesting and instructive account of 23 direct or pre-arranged experiments and of 32 unintentional experiments or examples occurring in practice showing the actual lateral pressure of earth; and concludes that "a wall which by Coulomb's formula was on the point of overturning has a factor of safety of at least two."

In view of the numerous assumptions involved, and in view of the lack of good reasons to justify these assumptions, and in view of the disagreement between theory on the one hand and experiment and experience on the other, it is little wonder that some persons do not put much dependence on the ordinary theory of the lateral pressure of earthwork.

In closing, permit a few words about another phase of retaining walls. One of the most common methods of failures of retaining walls, particularly upon compressible soil, is the tipping of the top of the wall forward, because of too great pressure on the soil under the toe of the footing. Unfortunately, the maximum pressure on the soil under the footing cannot be determined with any considerable degree of accuracy, because the amount, the point of application, and the direction of the resultant pressure of the earth are not known. However, it is wise to give special attention to this phase of the problem, and to err on the safe side by extending the footing outward at the toe.

CLOSURE.

The Author: The following is a quotation from the code of Hammurabi, dated about 2000 years B. C.:

> "If a builder build a house for a man and has not made his work strong, and the house has fallen in and killed the owner of the house, then that builder shall be put to death.
>
> If it kill the son of the owner of the house, the son of that builder shall they kill.
>
> If it kill the slave, . . etc.
>
> If the property of the owner it destroys, . . . etc.

---

*Proc. Inst. of C. E., Vol. 65, p. 140-241.

If he build a house for a man and did not set his work and the walls topple over, that builder from his own money shall make that wall strong."

As a result of the advance publication of this paper, I am advised that on a single system of railways in this country there are about forty abutments that are moving annually; periodical inspection and a record of movements are maintained, and it is the aim of the management to remove and replace them about one year before they would otherwise fall over.

The walls were built "just the same as some other walls were built," probably by rule-of-thumb, and are not on one of the largest systems of railways in the country, either. None of them are included in the list of forty given by Professor Howe in his work on retaining walls.

Some members, discussing this paper, intimate that the equations and diagrams appear to be complicated. They are, because of the four cases of stress with or without superimposed load over heel or toe, the consideration of the abutting resistance in front of the toe, the provision for a definite positive reaction at the heel, the introduction of a definite factor of safety, and the admission of a function to represent the varying physical characteristics of different earths. As previously stated, they are not intended for general use or to be used by those who are too indolent to familiarize themselves with all the premises and reasoning to results.

The person possessed of so much internal confidence that he can do visual engineering and attain results superior to the product of tests and mathematics should by all means cling to the abbreviated formulae, abbreviated walls and rebuild them when they tip or slide.

For the simple case assumed by Mr. Armstrong, the formulae given in Fig. 4 would reduce to $P_s = 0$, $R_s = 0$, $R_x = 0$, p_h min. $= 0$, p_t min. $= 0$, p_t max. $= 100\ y \div k^2 f$, $P_x = 50\ kh^2$, and the values of k and f should be selected from the factors in table of Fig. 4 for the various grades of material which the wall is to retain.

Using these values, Equation 1 becomes:

Minimum Base. Limit $p_h = 0$. $P_x \frac{h}{3} - W \frac{b}{3} = 0$.

$\therefore$ Minimum base, $b = 1.02\, h\sqrt{k}$ . . . . Eq. 0.

Minimum Base. Limit p_t max. $P_x \frac{h}{3} - p_t \text{ max.} \frac{b^2}{6} = 0$.

$\therefore$ Minimum base, $b = hk\sqrt{\frac{hkf}{y}}$ . . . . Eq. 2.

For each grade of material there is a depth of foundation, y, at which the values of b in the two equations will be equal; that depth is given by the equation

$$y = 0.96\, k^2 f h.$$

For footing depths greater than the value given by the equation for y, the base should be determined by Equation 0, and for depths less than given by the equation for y, the width of base should be determined by Equation 2.

In all cases the author considers it prudent to provide for a positive reaction at the heel equal to the tendency of the material to flow; this condition is expressed by making $p_h = 100\, hk^2$ in the case assumed.

Equation 1 of Fig. 4 then becomes:

$$\text{Minimum Base. Limit } p_h,\ P_e \frac{h}{3} + p_h \frac{b^2}{6} - W \frac{b}{3} = 0.$$

$$\therefore \text{ Minimum base, } b = h \sqrt{k \div (0.96 - k^2)} \ldots\ldots \text{Eq. 1.}$$

For each grade of material there is a depth of footing, y, at which the value of b in Equations 1 and 2 are equal, and this depth is given by the equation

$$\frac{y}{h} = k^2 f\ (0.96 - k^2).$$

This equation gives a constant ratio for each grade of material at which depth the value of b determined by Equations 1 and 2 will be equal; for greater depths, use Equation 1, and for less depths use Equation 2, to determine the width of base.

The ratio of base to height required to resist sliding is expressed by the equation

$$\tan.\ \Phi = \frac{50\, fkh^2}{48\, bh} \quad \therefore \frac{b}{h} = \frac{1.042\, fk}{\tan.\ \Phi}$$

This expression gives a constant ratio for each grade of material, but in most cases it is not feasible, with a horizontal base, to obtain the factor of safety desired against sliding. The abutting resistance of earth in front of the wall may be utilized and the base may be stepped or inclined to produce a stable design. Or, if all of the physical characteristics of the surrounding material are definitely known, it may be safe to reduce the factor of safety recommended.

These equations establish a few principles that will be convenient for designers, no matter what their ideas may be regarding the lateral pressures on the back of a wall, or what the allowable pressure at the heel and toe may be.

Principle.

1st. For every height of retaining wall there is a depth for foundation at which the base required to satisfy any pres-

sure selected for the heel of the wall and the base required to satisfy any pressure selected for the toe of wall will be equal.

2nd. For all retaining walls having footings below a certain definite limit the walls can be designed to satisfy the heel pressure without reference to the toe pressure.

3rd. For all retaining walls having footings above a certain definite limit the walls can be designed to satisfy the toe pressure without reference to the heel pressure.

4th. For all retaining walls there is a minimum ratio of depth of foundation to height of wall over which the width of bases should vary as the first power of the height.

5th. For all retaining walls there is a maximum ratio of depth of foundation to height of wall under which the width of bases should vary as the one and one-half power of the height.

It is quite general practice to select a preliminary design by making the base of a wall some percentage of the height and to compare designs by the ratio of base to height. This basis is ordinarily wrong, being only true of walls having relatively deep foundations. For all cases in which the dimensions are determined by the limit placed on the toe pressure as shown by Equation 2, the equation should be in the form $b = Ch\sqrt{h}$ (in which C is some specific constant) instead of the common form $b = Ch$.

Coefficients for any typical wall can be prepared to apply in Equations 1 and 2 and reduce the labor of designing to an absolute minimum.

To illustrate the use of these ratios and coefficients, assume a wall to have a net height of 10 ft. and that it is proposed to place the footing 4 ft. below the ground level at toe, making a total height, h, of 14 ft.

The designer may select any angle of friction in first line, any coefficient of friction in second line, coefficient of lateral pressure, k, in third line, or total horizontal pressure, P_E in fifth line that his tests or practical knowledge dictates, because either of these functions yield the same result when followed through the column to which it belongs.

I will select the case of an angle of internal friction = 30°.

Example 1. In the 30° column under "Limit values for h" and on line $y = 4$ find $h = 17$ ft. So use the coefficient for $b \div h$ on eighth line $= 0.626$, which gives a base $= 14 \times 0.626 = 8.75$ ft.

Example 2. If the depth of toe be made 3 ft. instead of 4 ft. and $h = 13$ ft. in "Limit values for h," and on line $y = 3$ find $h = 12.7$ ft. So use coefficient $\sqrt{k^3 f \div y}$, and on line $y = 3$ find 0.176; then $b \div h = 0.176\sqrt{h} = 0.634$ and $b = 13 \times 0.634 =$ 8.25 ft.

In same column below, for "safe pressures," $p_t = 1080$ lb. per sq. ft.

COEFFICIENTS FOR WALL OF TYPE P.
For a Level Fill, Weight of Earth 100 lb. cu. ft. Wt. of Masonry 144 lb. cu. ft.

Angle of Internal Friction		15°	20°	25°	30°	35°	40°	45°
Coeff. of Internal Frict'n.		0.268	0.364	0.466	0.577	0.700	0.839	1.000
Coeff. of Lat. Pres. k		0.589	0.490	0.406	0.333	0.271	0.217	0.172
Factor of Safety f		2.00	2.17	2.33	2.50	2.67	2.83	3.00
Total Horiz. Pressure P_E		$29.5h^2$	$24.5h^2$	$20.3h^2$	$16.7h^2$	$13.5h^2$	$10.9h^2$	$8.6h^2$
Ratio $b \div h$ Sliding $\frac{1.042fk}{\tan.\phi}$		4.58	3.04	2.12	1.51	1.08	0.76	0.54
Ratio $y \div h$ for Eq. 1.		0.425	0.375	0.306	0.236	0.174	0.122	0.0825
Ratio $b \div h$ for $p_h = 100 k^2 h$.		0.980	0.826	0.714	0.626	0.553	0.488	0.430
	y	Limit Values of h.						
For Values of h less than on line of Value of y use coefficient for Value of $b \div h$ above, or Eq. 1	3	7.0	8.0	9.8	12.7	17.2	24.6	36.4
	4	9.4	10.7	13.1	17.0	23.0	32.8	48.5
	5	11.8	13.3	16.3	21.2	28.7	41.0	60.6
	6	14.1	16.0	19.6	25.4	34.5	49.2	72.7
	7	16.5	18.6	22.8	29.6	40.2	57.3	85.0
	y	Coefficients $\sqrt{k^3f \div y}$						
For Values of h greater limits given above use Coefficient $\sqrt{k^3f \div y}$ and multiply by $\sqrt{h}$ for Ratio $b \div h$ or Eq. 2	3	0.369	0.292	0.228	0.176	0.133	0.098	0.071
	4	0.320	0.252	0.198	0.152	0.115	0.085	0.0625
	5	0.286	0.226	0.177	0.136	0.103	0.076	0.055
	6	0.261	0.206	0.161	0.124	0.094	0.069	0.050
	7	0.242	0.191	0.149	0.115	0.087	0.064	0.047
	y	Safe Pressures						
Pressure per sq. ft. at toe of Wall or $p_t = 100y \div k^2f$.	3	435	570	780	1080	1530	2250	3390
	4	580	760	1040	1440	2040	3000	4520
	5	725	950	1300	1800	2550	3750	5650
	6	870	1140	1560	2160	3060	4500	6780
	7	1015	1330	1820	2520	3570	5250	7910

Table 5.

EXAMPLE 3. If with the footing at a depth of 4 ft. it is considered safe to let the pressure down to zero at the heel, use *Coef.* $\sqrt{k^3 f \div y} = 0.152$ and $b \div h = 0.569$, when the base becomes $14 \times 0.569 = 7.96$ ft.

Same column below, for "safe pressures," $p_t = 1440$ lb. per sq. ft.

In all three examples reading on sixth line, the base should be 1.51 h to resist sliding with the factor of safety 2.5 as desired, which indicates that the base of wall should be stepped or inclined.

With the base ratio selected, the designer can enter the conversion diagram, Fig. 8, and select practical dimensions for concrete or reinforced concrete walls with the assurance that they will require but little modification when finally checked by more detailed processes.

When an inclined or stepped base is required to resist sliding, the designer should use Type V wall in conversion diagram, or dimensions selected at some point between the Type V and Type L curves and revise the section shown in Fig. 4, as indicated by dotted lines.

The origin of the rule to make the base four-tenths of the height may be explained as follows:

Assume a typical wall of trapezoidal section with vertical back, level fill and thickness of wall at top equal one-half the thickness at base, also that the masonry weighs 150 lb. per cu. ft. The weight of a section of wall 1 ft. long will be $0.75bh \times 150 = 112.5bh$, and its center of gravity will be at a distance of $0.389b$ from the back. Take the horizontal pressure as expressed by Mr. Armstrong's equation, $15h^2$.

Taking moments about a point in the base at a distance of one-third b from the back, the value of p_h may be neglected and there results

$$15h^2 \times \frac{h}{3} + 112.5\ bh(0.389 - 0.333) = p_t \times \frac{b}{2} \times \frac{b}{3}$$

Whence $b^2 = h^3 \div (0.033p_t - 1.26h)$........(a)

When $p_h = 0$, the resultant pressure passes the base at the middle third and for this condition $\frac{1}{2}p_t b = 112.5bh$, or $p_t = 225h$.

Substituting in (a),

$$b^2 = h^3 \div (7.5h - 1.26h) = h^2 \div 6.24 = 0.16h^2 \text{ nearly,}$$
$$\text{or } b = 0.40h.$$

This is the good old thumb rule that has probably caused more retaining wall failures than any other method of designing.

In reducing Equation (a) to the form $b = 0.40h$ it will be noticed that the value of p_t was determined by h, namely, $p_t = 225h$. So the equation amounts to making the toe pressure a function of the height of the wall h, when it should be a function of the depth of toe, y.

For a wall 10 ft. high, $p_t = 2{,}250$ lb. per sq. ft.
" " " 50 ft. " $p_t = 11{,}250$ " " " "

and in either case the factor of safety may be greater or less than one, depending on the depth of the toe; generally less when the abutting resistance of the toe and possible friction on the back of the wall are neglected.

For $p_h = 0$ and for every grade of material there is some depth of toe, y, at which the proper width of base may be $0.40h$, and for all other depths of toe in the same grade of material the ratio $b \div h$ should vary as $\sqrt{h \div (0.033p_t - 1.26h)}$ for this typical wall.

This variable ratio is not ordinarily used if the forty walls illustrated in Mr. Howe's treatise on retaining walls, or thirteen walls listed on page 598, first edition of *American Civil Engineers' Pocket Book,* fairly represent good practice. It is notable, however, that 69% of the thirteen walls mentioned have slipped, tipped, or tumbled.

The requirement of a larger ratio of base to height, as the height increases, is clearly indicated in Figs. 5, 6, and 7 by the inclined and slightly curved lines for "Minimum Base a/c Toe Pressure" in those figures.

I fail to comprehend how Mr. Armstrong used Rankine's theory, the same as Equation 3, determined the value $P = 14.3h^2$ mathematically, seasoned the mathematical porridge with 4.9% of good common sense, and determined the abbreviated formula $P = 15h^2$ as his standard, without committing himself to the theory, mathematics and a recognition of a value for ϕ to such an extent that he could not later suggest "to assume a granular material of proper weight," and presumably an assumed value of ϕ, "which are nearly enough correct, and design your wall accordingly," without stating what proper weight of granular material should be assumed and what kind of a guess should be made on its lateral pressure.

It appeals to me as better practice to determine all the factors as nearly as possible by tests and mathematics, apply them first, and do your guessing at the end of the operation,—if any guessing must be done. I can see no reason why accredited tests and mathematics in such a case will not at least aid a man endowed with the sixth sense in guessing at advisable dimensions for a retaining wall—if he insists on guessing.

Mr. Armstrong advises discussion mathematically to determine the *laws* governing designs rather than actual working formulae. As I understand this matter, common sense, experiments, and logic determine the *laws,* mathematics delivers the quantitative analysis, and a working formula is produced by dropping the decimal figures or their equivalent.

This debater also states, "a structure designed entirely on mathematical deduction often proves to be weak in many essential features." I was educated to believe that mathematics was the most exact of all sciences. I still believe it is, and shall urge all others to the same belief until the debater presents a concrete case to disprove it. I fear he has been misled by some misapplication of mathematics.

There appears to be mystery in some minds regarding what I mean by a factor of safety. This is the first time in 35 years of my practice that a question as to the meaning of the phrase has been raised, so I feel justified in using a small percentage of that time to give two interpretations other than my own:

From Rankine's *Civil Engineering,* page 222:

"A factor of safety when not otherwise specified means the ratio in which the breaking load exceeds the working load."

From *American Civil Engineers' Pocket Book,* page 273:

"The factor of safety is the number by which the ultimate stress must be divided to give the working stress."

It is with that meaning I have used a factor of safety in my equations.

Some arguments in favor of the use of the elastic limit or yield point as the basis of a factor of safety have been advanced, and with good reason in some cases, but the fact that the ultimate strength of nearly all materials is a more definite quantity and easier to determine, has prevented the use of the factor to express the relation between the working stress and the elastic limit in engineering structures.

In reply to the statement "I do not know of any engineering structure to which exact mathematics in actual design is less applicable than retaining walls," I will state that I do not know of any engineering structure to which actual mathematics is less exactly applied than to retaining walls; the record of partial and total failures in these strustures is not a very good argument in favor of less mathematics.

Cohesion in many grades of earth prevents the accurate determination of the angle or repose, but that the readers may not be misled or discouraged by the statement that nobody will ever know what the angle of internal friction of the material underlying the city of Chicago is, I will refer them to the experiments of E. P. Goodrich and advise them that considerable is already known in regard to this physical characteristic of earth.

These experiments have been before the public about ten years, and for each grade of material the results agree closely with a straight line. In comparison with the representation of tests on steel columns by the straight line formulae, used with confidence by most bridge engineers, the latter are easily distanced.

Referring to Mr. McCullough's discussion: As stated in my argument on the tenth page of my paper, the wedge of least resistance, as ordinarily applied by bisecting the angle 90° — ϕ gives accurate results for *one case only;* that is, when ϕ is the angle of internal friction, when the surface of the material retained is level and without superimposed load, and the back of wall is vertical; in all other cases the method advanced in this paper will yield more reliable results.

In most cases the variation of the approximate method is not large and may be permissable in preliminary studies, but for final design the unknown variation should be eliminated by using the more accurate analysis.

Sir Benjamin Baker's extensive experience in building retaining walls has generally inspired great confidence in his paper on this subject. He says "experience has shown that a wall [to sustain earth having a level top surface] whose thickness is one-fourth of its height, and which batters one or two inches per foot on the face, possesses sufficient stability when the backing and foundation are both favorable." Also, "as a result of his own experience, the author (Benjamin Baker) makes the thickness of retaining walls in ground of an average character equal to one-third of the height from the top to the footings." His papers may seem to some to be the last word in English on retaining walls, but as no limit is placed on the depth of the foundation, no limit is placed on the height of the wall, and as this country has furnished numerous failures of walls having 50 to 100% more liberal proportions, it is time to investigate the characteristics of the earth to be dealt with, apply mathematics, and revise the code.

The factors of safety I have recommended for use in subway construction in Chicago are larger than I would apply in most cases. The damage that may be avoided by this precaution is well illustrated by the recent failure on the Marshall Field & Co. building on Randolph Street.

Referring to discussion of Messrs. Grant, Hayford and Tratman: The engineering paper in which the failure of the wall on the Barge Canal was reported states that the initial movement of only ¾ in. occurred when the filling was dropped 10 to 40 ft. Thereafter *more care was exercised in placing the filling* and ten days later the wall started again; in four hours it moved out 18 ft. at the top, 10 ft. out at the bottom, and down 4 ft. Reproductions from photographs in another journal show the fill about three-fourths completed, with no indications of high dumping and a reasonably level even fill.

If the illustrations in the paper can be relied upon, the failure is clearly due to an excessive toe pressure and no toe depth to counterbalance the conjugate pressures resulting from the toe pressure.

No speculating is necessary as to the cause of the failure. If it was the result of impact the wall would come to rest when the vibration was absorbed instead of moving on for four hours. If it was due to a slippery bottom the movement would have been nearly horizontal. Instead of either of these conditions, the wall ploughed down into the bottom of the canal and rolled up a toe to resist the conjugate pressures developed, and stability was restored. No one was killed and no hara-kiri resulted because of the incident.

In the account that I read of the reconstruction of the wall, it was stated that the cross-section was enlarged, without stating where or to what extent. Exact information covering these changes and any other precautions taken to avoid a recurrence of the failure would be interesting.

I fail to get the logic of Professor Hayford's discussion. In one place he says, "Mathematics simply furnishes one a means for getting at the *correct logical* conclusion from a given set of facts or a given set of assumptions." "It gets from certain facts or certain assumptions the proper logical conclusion provided your facts or assumptions are quantitative." In another place he advocates the general use of "rough mathematical methods" to conserve one's energies to study assumptions.

I will compare such a process with a navigator who having consulted all his charts and determined as nearly as possible the location of a new harbor and determined the course for his ship, steers it roughly and takes a chance of landing in the harbor or on either side of it.

The argument affords any of the professor's pupils who happen to see it a fine opportunity to relieve the monotony of classroom exercises with pertinent but heckling questions.

Referring to Mr. Lacher's discussion: The service of bridges in holding up abutments is not monopolized by public highway constructions. I have seen a number of railway bridges performing the same benevolent act. I cannot aid you on your economic abutment problem. Try some benevolent society or an insurance agent.

Referring to Mr. Stern's discussion: The eulogy of the visual engineer, his sixth sense, and his ability to look at a design for a bridge and know instinctively whether or not it is right, is unfortunate in this discussion, because the final decision as to what is or is not right in bridge construction is almost invariably determined by computation.

The visual engineer with proper preliminary training and extensive practice may be able to detect gross errors or omissions that should have been discovered by the assistant engineer or the lowly checker, but all exact determinations fall to the aides who have gained and retained the mathematics covering the case; the visual engineer must take the siding to give a clear track for the results of tests and mathematics.

For over 30 years the visual engineers have been using either their sixth sense, or some empirical rule which makes the width of base of a wall a percentage of the height, or guessing at the lateral pressures and safe resistance of the earth in foundation, without discovering that. Whatever the pressure on the back of the wall may be, and whatever the safe resistance of the earth should be, the base of walls of different height should vary as the height of the wall multiplied by the square root of the height in all ordinary cases.

Referring to Mr. Vent's discussion: If an hydrostatic equivalent for a surcharge is applied, the zero point of pressure would be at some distance above the top of the wall and the center of pressure would be located too far above the base. If that part of the pressure above the top of the wall is neglected, the total pressure will be too small and the center of pressure too low; and if the surcharge or superimposed load does not extend to the back of the wall, as is nearly always the case, the equivalent hydrostatic theory is quite irrational.

In one sentence he advocates the use of a hydrostatic equivalent and in another states that "the ratio of thrust to vertical loads changes somewhat in the different heights of abutments," without stating whether it is greater or less, at higher or lower points or how much.

The other features of Mr. Vent's discussion appear to be undebatable without hearing how he knows his walls will stand up; it is the number that have failed with more liberal proportion that leads me to be suspicious.

Referring to Professor Baker's discussion: I am pleased to acknowledge my error and apologize to Professor Baker for mixing the dates of his interesting discussion on earth pressures and hope to see a thorough revision of his criticisms in future editions of his work.

The theory of conjugate pressures as developed by Rankine is a strictly mathematical discussion of the highest order and its application to practical problems is not generally understood; it is not surprising then that some writers are slow in adopting it and that it is sometimes discredited.

Evidence that it can be safely applied to any homogeneous material from a fluid to the hardest solid is furnished by steel and other materials under stress in the lateral deformation, now measured and known as Poisson's ratio, although 30 years ago this property had not been dignified with an imported name.

Solids in which the compressive strength is large compared with the tensile strength, as cast iron and concrete, furnish diagonal fractures in compression tests to indicate the maximum angle of obliquity for internal stress, and in granular materials the measured pressures and planes of rupture are in good accord with the conjugate theory of internal stress.

If to a clean granular material one applies a little foreign matter such as loam, cement, rootlets, or water or some special condition of stress such as, shaking, tamping, or puddling, he should expect a change of the physical characteristics.

A skilled moulder will take fine sand that when loose in a pile will stand at an angle of 45° or less, sift it into a thoroughly granular condition into a flask, apply moisture and pressure as his skill dictates, and cause it to stand vertical or overhang in almost any intricate form desired. He knows that an excess or deficiency of moisture or pressure, or shock, or vibration will destroy his structure; its integrity is founded on *cohesion* and its life limited.

Rankine gives similar reasons for ignoring cohesion in determining the stability of structures in earth, in the following words: "A structure of earth, whether produced by excavation or embankment, preserves its figure at first partly by means of the friction between its grains and partly by means of their mutual cohesion or tenacity; the latter force is considerable in some kinds of earth such as clay, especially when moist. It is by its tenacity that a bank of earth is enabled to stand with a vertical or even overhanging face, for a few feet below its upper edge; whereas, friction, alone, as will afterward appear, would make it assume uniform slope.

But the tenacity of earth is gradually destroyed by the action of air and moisture and by the changes of the weather; so that its friction alone is the only force which can be relied upon to produce permanent stability."

It is so well known that in caving, banks generally cleave in a curve with the least slope at the base and the greatest slope at the top, when the material is homogeneous, and that the curved face is almost invariably reduced approximately to a plane by the action of rain, frost, and other conditions of weather, that after showing, in discussion of Fig. 3, that a variation of 20° in the position of the plane or curve does not radically affect the total lateral pressure on a wall, it does not appear to be appropriate or profitable to devote more space to the discussion of this transitory condition of cohesion in a paper dealing with stabilities.

The report of experiments conducted by E. P. Goodrich indicates a careful study of previous experiments in this and foreign countries, and upon page 298 of Vol. 53 of the Transactions of the American Society of Civil Engineers he states: *"They show conclusively that Rankine's theory of conjugate pressures is correct when the proper angle of friction is used."*

A vertical trench in a body of earth having a horizontal top requires horizontal bracing *only* to insure stability. If the line of trench is transverse to a steep slope, it requires inclined bracing only, and I hope all engineers know which way to incline the bracing. A retaining wall that will supply the resistance afforded by the braces so that they and the earth on one side may be removed is all that is required to insure stability. From this illustration the direction and point of application of the resultant stress in this simple case is so evident that it seems unnecessary to submit proof, but I will apply a little *"Reductio ad absurdum."*

To throw more light on these disputed points let us concede, for an example, that the direction and point of application of the resistance offered by a retaining wall is as Professor Baker argues —in the direction of motion—and that the point of application is between 0.35*h* and 0.50*h* from the base of wall.

The forces necessary to equilibrium are as represented in Fig. 9. It is not necessary, in this argument, to know the magnitude of any of them.

We know that the resultant weight *W* of the wedge *A B C* acts through its center of gravity; we know that it may have a component *N* perpendicular to the plane *B C*, and that this component multiplied by the coefficient of internal friction, tan. ϕ, will give the tangential stress on the plane *B C* due to frictional resistance; and if a line *W F* making an angle ϕ with the line *W N* be drawn, it will represent the direction and point of application of the resultant stress on the plane *B C*.

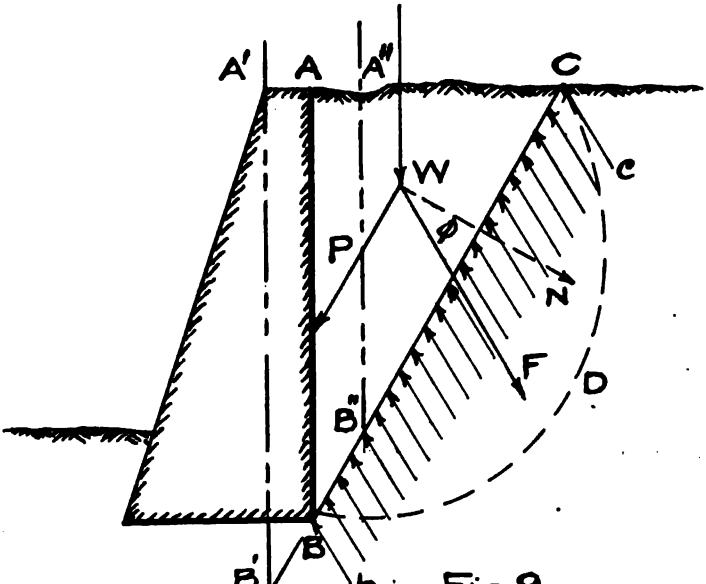


Fig. 9.

The location of the resultant is above the center of *B C*, so the trapezoid *B-b c-C* may represent the distribution of pressure on the plane *B C*.

It is quite irrational to presume that a little group of grains of material about the point *C* can either produce or resist the stresses as represented by the line *C c*, and it is absurd to presume that any such condition of stress can exist except between two solids.

If it is claimed that the surface of rupture will be a curve as

B D C, the position of *W* must be moved to the right and the distribution of pressures would be more absurd. If it is claimed that some curve as *B D C* may represent the distribution of pressure, the condition of stress in the vicinity of *C* should not be changed if we assume the location of the back of our wall on the lines *A′ B′* or *A″ B″*, in which case neither our curve of rupture or curve of pressure would meet the bottom of the wall.

The simplest conditions of statics require that the point of application of *P* be at one-third the height of wall from the bottom and that in this case its direction be horizontal.

If the wall is located where it will not be exposed to the action of water, frost, or any other disturbing element, and a slight yielding of the wall or fill to develop friction on the back of the wall is permissible, the method of treatment is indicated in Fig. 2 and the original text of this paper.

Tests to determine the "plane of rupture" in material devoid of cohesion have been made by placing different colored layers of the same material one above the other and releasing the lateral support until a rupture occurred in the body of the granular material. The location of the rupture was clearly defined by the offsets in the various strata; the surface was a clearly defined plane instead of a curve, and the volume that moved conformed with the theory of a wedge of least resistance and Rankine's theory of conjugate stresses.

In some report of experiments that I have read, but am not now able to locate, it is stated that when tests made to determine the position of application of resultant were made against a plane hinged at the bottom, the resultant appeared to be above the third point, and when the plane was hinged at the top the resultant appeared to be below the third point above the bottom. This seems to prove that the true location is at the third point.

The comparison of tests on grain in the bins of an elevator with the conditions ordinarily found in earth about a retaining wall, suggests a comparison of the hydrostatic conditions in a capillary tube and an open ocean; it is not quite as bad, but on the way.

The statement in relation to Rankine's theory, "According to this theory, a wall may be more stable with a surcharge than with a level top surface, because of the difference in direction of thrust," requires radical revision, to be in accord with Rankine's theory, by the addition of the following words: "and less stable because of the *magnitude* of the thrust." The net result of the two statements is the opposite of what the professor states regarding its stability.

In making the comparison, it seems, too, that friction on the back of wall has been neglected in the case of the level top and included in the case of the surcharge, which is an additional error.

In the experiments of Dr. H. Müller-Breslau I understand the friction between the material and the plane supporting it was *not eliminated,* so the direction of resultant pressure in the various tests should be as he found them; the same may be said of the tests of Sir Benjamin Baker.

The use of the factors of safety I have advocated, will result in toe pressures substantially lower than those in common use which have caused most of the partial and total failures. "Extending the footing outward at the toe" will accomplish the same result but in a rather indefinite manner.

CONCLUSIONS.

1. The weight per cubic foot and coefficient of internal friction of the material used should be determined as nearly as possible in all cases.
2. Tests of foundations should be made at various depths with the earth restored about the testing plunger and tamped to its original density before the test loads are applied.
3. Cohesion within the material and friction on the back of walls should be neglected in designing because the error, if any, in so doing is on the side of safety.
4. The theory of Rankine, with the angle of internal friction substituted for the angle of repose, should be used for both vertical and lateral pressures and resistances on walls and foundations.
5. For irregularly-shaped surfaces and surface loads the method proposed in this paper is urged for trial and comparison with the results of other methods.
6. The permissible pressure upon a foundation should vary with the material and the depth it is located below the lowest surrounding material or the depth equivalent of the permanent surface load; the depth should be so adjusted as to place the pressures produced by variations in surface loads between the limits of active pressures and passive resistances.
7. The permissible pressure at the heel of a wall should not be less than the pressure resulting when the material is saturated to the height of positive drainage.
8. The lateral pressure of material permanently in front of the wall should be used in determining net moments and resistance to sliding.
9. When the base of the wall is inclined to resist sliding, the abutting resistance of the earth above the level of heel and below the level of the toe is the measure of the resistance secured by the inclined or stepped base.
10. A factor of safety of two to three should be required to prevent rotation and sliding, the amount depending on the material and the damage that may result from a failure.

To all who have participated in the discussion of this paper I extend my sincere thanks for their aid in bringing out points that otherwise would not have been mentioned or not as fully de- ed.

THE MANUFACTURE OF BY-PRODUCT COKE

T. V. SALT, M. W. S. E.

Presented October 6, 1913.

IN GENERAL.

Before going into the process of the manufacture of by-product coke, it would perhaps be desirable to point out for the benefit of those who are not familiar with the subject, a few of the economic and commercial aspects, the present status and future possibilities of the by-product coke industry.

Coke is the residuum of a coking coal after the latter has been subjected to the process of distillation of high temperatures. The process of distillation is carried out in two ways: In beehive ovens with only partial exclusion of air; and in by-product coke ovens and gas retorts with entire exclusion of air.

In the beehive type of oven, the coking process is carried on with a partial loss of fixed carbon due to combustion in the ovens and with complete loss of by-products.

In the by-product type of oven the process of coking is merely one of distillation, with complete recovery of by-products and without any accompanying reduction in fuel value, as combustion does not take place in a by-product coke oven.

Inasmuch as the coke produced from the manufacture of gas in any modern gas retort is not generally suitable for metallurgical purposes, this type will be excluded for the present.

The average yield of coke in beehive practice is approximately 65%. The average yield in by-product practice is approximately 75½%. This difference is accentuated by the enormous production of the Gary and Joliet by-product plants of the Steel Corporation, due to the high fixed carbon content of the mixtures used at these plants. Nevertheless, the normal yield obtained in by-product coke ovens represents a tremendous saving during the course of a year's operation. You are referred to an article fully illustrating this, in the United States Geological Survey paper on "The Manufacture of Coke in 1912," by Edward W. Parker.

The by-product coke industry is directly allied to two important industries: (1) The manufacture of pig iron; and (2) the manufacture of illuminating gas. A further field is its universal use as a fuel to replace crude coal.

As Mr. Salt was unable to be present, Mr. H. B. Kirkpatrick, M. W. S. E., with H. Koppers Company, presented this paper and offered discussion.

Reference: Technical Paper 50, Metallurgical Coke, by A. W. Belden, Bureau of Mines, U. S. Department of the Interior. Washington, D. C., 1913.

PRODUCTION OF PIG IRON.

The following table shows the increase in the production of pig iron in the United States as compiled from the records of the American Iron and Steel Association, from 1890 to 1912, inclusive:

Year	*Gross Tons*
1890	9,207,703
1891	9,279,870
1892	9,157,000
1893	7,124,502
1894	6,657,388
1895	9,446,308
1896	8,623,127
1897	9,652,680
1898	11,773,934
1899	13,620,703
1900	13,789,242
1901	15,878,354
1902	17,821,307
1903	18,009,252
1904	16,497,033
1905	22,992,380
1906	25,307,101
1907	25,781,361
1908	15,936,018
1909	25,795,471
1910	27,303,567
1911	23,649,344
1912	30,000,000

It will be seen from the above table that the increase in production of pig iron for the past 20 years has been 225%—a production greater than that of Germany and England combined.

ANNUAL ADDED CAPACITY 1905-1912.

Year	*Capacity*
1905	1,292,000
1906	1,135,000
1907	2,065,000
1908	1,185,000
1909	1,930,000
1910	1,794,000
1911	565,000
1912	1,000,000

This is enough to illustrate the importance of the pig iron industry and its possible growth.

PRODUCTION OF COKE.

Year	*By-Product Coke*	*Beehive Coke*	*Total*
1893	12,850	9,464,730	9,477,580
1901	1,179,900	20,615,983	21,795,883
1907	5,607,899	35,171.665	40,779.564
1908	4,201,226	21,832.292	26,033,518
1909	6,254,644	33,060,421	39,315,065
1910	7,138,734	34,570,076	41,708.810
1911	7,847,845	27,703,644	35,551,489
1912	11,048,489	32,868,345	43,916,834

It will be seen from the above that we are at the present time manufacturing only about 25% of the total coke produced in the

United States in by-product coke ovens. It is unnecessary to dwell on the wastefulness of the beehive oven; it has been completely replaced in Europe with by-product ovens, and it is only a question of time until it will be completely replaced in this country. It is not now considered in installations for the production of coke, except in localities where it is advisable and almost economically necessary to continue beehive practice. The future field for the by-product coke oven industry in this particular is assured.

Reference to the above table will show that during 1912 there were practically 44,000,000 tons of coke made in the United States, of which amount approximately 11,000,000 tons were made in by-product coke ovens. Assuming an average beehive recovery of 65%, there were approximately 54,000,000 tons of coal converted into coke without the recovery of by-products, and practically the entire amount was consumed in the manufacture of pig iron.

On a conservative estimate, it is safe to say that the loss of these recoverable by-products amounted in value to a sum equalling the total coal that went into the production of the entire 44,000,000 tons of coke.

By-product coke when properly made is equal in quality to the best grade of beehive coke.

BY-PRODUCT COKE IN ITS RELATION TO THE BLAST FURNACE.

There is one disadvantage in connection with the by-product coke oven. It is a fact that many available coals for making excellent coke in Beehive ovens are not suitable for use in the by-product oven, as the coke so made, while satisfactory chemically and physically, breaks up into pieces too small for use in the blast furnace. There is no question but that this coke could be used for domestic purposes, but unfortunately this is an undeveloped market and will be discussed later. It is also a fact that many coals available for use in the by-product oven and making excellent metallurgical coke cannot be used in the Beehive oven. Therefore, we are forced to admit that both types of ovens are restricted to certain grades of coal. In order to remove the objection to the by-product oven, we have merely to remove the objection to the size of the product from certain coals. This can be done in two ways: First, we must learn to coke these coals in such a way that the objection to size can be removed; second, we must ask the blast furnace men to learn to use the small coke. If the coke produced is satisfactory in all other respects, it should not be rejected on account of size, provided that the size of the coke is suitable to permit its use at the tuyeres of the furnace.

REQUIREMENTS OF BLAST FURNACE COKE.

Practically all pig iron in this country is made with coke; yet there does not appear to exist any definite standard specifications for the purchase of blast furnace coke. Common practice and usage accepts a coke as satisfactory that possesses the following essentials or characteristics:

1. Chemical Composition:

(a) An ash content of 10% or under; in other words, the maximum percentage of fixed carbon with corresponding high fuel value. This does not mean that coke containing a higher percentage of ash is in all cases rejected, but beyond 10% it adds considerably to the cost of producing pig iron and is therefore undesirable.

(b) A sulphur content of 1% or less.

(c) A phosphorous content low enough so that the pig iron will not be unduly affected.

2. Physical Characteristics:

Under this heading is placed the cellular structure and arrangement, on which depends its compressive and abrasive resistance to the burden in the furnace. Cellular displacement or porosity determines the extent of the spherical area exposed to the action of the blast and rapidity of heat development. The average blast furnace coke has a porosity of from 47% to 50%.

The prime function of blast furnace fuel is to furnish heat. Therefore the higher the percentage of available carbon the fuel contains, the greater its value.

The necessity for low sulphur and ash content is explained by the fact that its removal by fluxing requires added material and heat, the heat being furnished by the carbon in the coke; the added material will be, roughly, twice the weight of limestone per unit weight of ash, and from three to three-and-a-half times the weight of limestone for every unit weight of sulphur. It is generally estimated that about 25% of its own weight in carbon is required to melt the slag.

These are approximate figures and are given simply to show how the purity of the fuel influences the capacity and quality of production of the blast furnace. As indicated above, one of the most important factors determining the value of fuel is its size.

It is generally conceded among blast furnace operators that the coke in its descent through the blast furnace is only slightly dissolved by the ascending CO_2, and reaches the level of the tuyeres practically in its original form; it is then reduced to CO. Just what precise size the coke should be at this point, I have never been able to find out, but the furnace men in general agree that the more uniform the coke at this point, the faster and easier the furnace works. This being the case, it should not be difficult to definitely state, providing the coke is properly coked, what the size of the coke should be when charged into the furnace. If this could be determined and definitely specified, many available coals that make excellent coke would be thrown upon the market to be used immediately in the manufacture of by-product coke, and the economic gain to the user would be very great.

AVAILABLE COKING COALS.

It seems that there are two essentials lacking in the necessary combination to enlarge the field of available coking coals: First, specific knowledge of the actual phenomena of coking; second, precise and definite knowledge in the art of its use in the manufacture of pig iron.

1. Specific Knowledge of the Actual Phenomena of Coking. There has been a great deal of technical data published during recent years relative to the behavior of coals under heat. A serious effort has been made to find out why one coal will coke while another will not. The results of these investigations to my mind prove conclusively that the coking quality of the coal depends on the amount and character of certain of the heavier tarry compounds, particularly those of a resinous character. This would indicate at first glance that a coal containing the largest percentage of tar would be the best coking coal. With our present knowledge of coking, however, we know that this is not the case. It might indicate that the heat condition under which the coal is coked is the most important thing in the entire phenomena of coking, and it may be that with certain coals we will have to work with higher temperatures than those which we are accustomed to at present. There is no question in my mind that this is the crux of the whole thing, and is it not important enough to follow along big, practical lines for its commercial importance? Laboratory investigations are futile. Single oven tests do not mean anything. I have in mind a detached block of ovens equipped with recovery apparatus and operated as an experiment station. The coke, gas, and by-products could be utilized commercially precisely as the product of the plant proper. The advantage of having this plant as an adjunct to a going concern is that it would be absolutely uninfluenced by any conditions other than those created by the actual carbonization of the coal itself. It would depend for its gas on the main plant, and wherever there is a large available surplus, this would positively insure a constant uniform supply of gas to the ovens. It could be connected to an auxiliary power plant where the danger of fluctuation due to shut-downs would be eliminated. In other words, it could operate continuously under known established conditions which would be constantly identical. The same coal would be used with every possible combination of conditions until actual authentic data were established, prescribing with positive exactness the conditions under which that coal should be coked to produce the most desirable results. These tests could be continued indefinitely with very little cost to a plant already in operation. The tests would not be indicative but a standard of what a plant built along the same lines would produce.

I venture to say that in the course of a few years information of positive and incalculable value will be established. The most important essential in the whole thing is patience and surely the object is worth the price.

February, 1914

2. Precise and Definite Knowledge in the Use of Coke in the Blast Furnace. With reference to the lack of precise and definite knowledge in the use of coke in the blast furnace, I can imagine the effect that this statement will produce on the average blast furnace man, and am very glad this statement is being made to a somewhat friendly audience. Nevertheless, such a statement must be conceded a fact. The reason is very clear. Up to 1907 or 1908, the standard fuel for the entire country was Connellsville Beehive coke. You are all familiar with the loaflike structure of this coke, and its size was considered one of its strongest virtues. The blast furnace man did not have to bother about his fuel, and his researches did not go beyond what the local condition from day to day necessitated. As recently as 1907 and 1908 it was considered impossible to operate with by-product coke and get the same results as with Connellsville coke. I think the principal objection was on account of its color and size. When we started the Joliet coke plant in 1907 we were visited by coke and blast furnace experts and they were all unanimous in stating that the coke was much too small. We broke it up into too small pieces and the results obtained from the use of that coke at Joliet, South Chicago and Gary have demonstrated how much they were mistaken.

The spherical diameter of the entire coke production at Joliet would not average 4 in. About 40% of the coke will stay on a 2½ in. screen; 40% to 44% will go through a 2½ in. screen staying on a 1⅛ in. screen and the balance will go through the 1⅛ in. screen. The results obtained at Joliet encouraged the management of a certain blast furnace plant to experiment with crushed coke. Every pound of coke used at their blast furnace goes through a 3½ in. roll crusher, producing the following sizes, which are the averages for 1912:

On 2 in. screen, 75%.
On 1½ in. screen, 17%.
On 1 in. screen, 6%.
On ¼ in. screen, 1%.
Through ¼ in. screen, 1%.

The coke is produced from a mixture of 70% high volatile coal and 30% Pocahontas, making an average volatile matter in the mixture of 29% to 30%. With this mixture and this size coke, a decided improvement was obtained in the furnace and they now have a coke consumption of about 2300 lb. on a 53% yield, using a large percentage of briquetted ore. Other furnaces are contemplating the same step.

It will be only a question of time until this problem of size is solved satisfactorily, but would it not be better if every blast furnace man in the country would turn his attention to this problem and thereby hasten its solution? The economic advantages to be gained from such a solution are tremendous, and would certainly mean, in many instances, the installation of by-product coke oven plants, cheaper coke, and cheaper pig iron.

Referring again to the coke-oven operation, I cannot but take time to express a desire that less time and money be spent on the technical side of the industry and a little more on the commercial side. By all means, strive to obtain the greatest possible recovery of by-products, but do not overlook the fact that the revenues to be gained from this source in the future are now slight compared to the returns that could be obtained in finding out the character of certain coals and the method of successfully coking these coals that we are at present rejecting. This is a problem absolutely up to the coke-oven operators. The fact that with the enormous production of coke and the widely scattered localities of the blast furnace, our lack of knowledge on this great economic question practically restricts us to the use of a mixture of two certain coals, is deplored.

Summed up, the by-product coke oven is so close in its relationship to the blast furnace that it is difficult to determine where the relationship begins and ends. It is without doubt an auxiliary to the blast furnace and should be operated for the particular blast furnace where its product is to be consumed. There is no question as to the quality of the fuel produced in by-product ovens, and the fuel is today accepted everywhere. In Germany there is not a pound of fuel used that is not manufactured in by-product coke ovens. England is rapidly getting into the same position. Japan has two by-product coke plants in operation and several others under contemplation. The same can be said of China. It is possible that in the near future we will be in the position of shipping pig iron manufactured from coke made in American by-product coke ovens to the Pacific Coast.

Another important point should be mentioned before closing this particular subject. The Panama Canal will throw open to us the Pacific markets and a great export trade. There is magnificent ore in Texas of the finest possible quality and in unlimited quantity. There is also excellent coal in the South, but, as is true of the coal in the North, certain grades are considered better for coking purposes than others. In other words, wherever pig iron is manufactured, there will be, eventually, by-product coke ovens, and its development is restricted only by the extent of the manufacture of pig iron.

THE BY-PRODUCT COKE OVEN IN THE MANUFACTURE OF GAS:

It has been stated that the by-product coke oven is not so well adapted to the manufacture of illuminating gas as so-called gas retorts. This is not a fact. Continental practice has demonstrated without any question that as regards volume and character of product, the by-product coke oven is just as well adapted to the manufacture of illuminating gas as any gas retort, whether it be vertical, inclined or through horizontals. The unfortunate part of it is that we are up against the same proposition as the gas maker would be if he had no water gas plant. It is impossible to evolve a gas from a coal that will meet with the present universal municipal requirements in practically every state of the Union. I refer to the candle power, which is antiquated and altogether unnecessary.

The modern incandescent mantle depends for its illumination upon temperature only, and if the gas contains the necessary heat value to give the maximum luminosity on combustion, the candle power has no bearing whatever on its value. Mantles are becoming cheaper and their universal use is surely in sight. It is true that the constituents of coal gas; that is to say, those vapors on which the gas mainly depends for its illuminating value, have a large thermal value, but such constituents are only a small percentage of the entire gas volume—not more than 3% or 4%—and they can be recovered from the gas as a marketable product without reducing the heat value of the gas more than 5%. I refer to the extraction of benzol. When a gas is debenzolized, it is absolutely free from naphthalene, a tremendous advantage in its distribution and transmission, and is adequate in every sense for the purpose of illumination in conjunction with mantles.

In regard to the use of gas for domestic and commercial purposes, it is needless to dwell on that phase of the question. Candle power is not a factor. It is plain, therefore, that gas should be sold in the United States on a heat basis, the same as in all other civilized countries. Gas that contains from 550 to 600 B. t. u.'s is adequate for any purpose for which it can be used. Wisconsin has the following municipal requirements throughout the State:

No candle power; the gas must have a total heating value of 600 B. t. u. per cu. ft. when referred to 30 in. pressure and 60 deg. F. The minimum shall never fall below 550 B. t. u. The sooner every other state in the Union follows this precedent, the better it will be for the gas industry and all parties concerned. The consumer has some rights in this matter, and if a gas can be produced cheaper by the elimination of unnecessary and foolish restrictions, it is only right and proper that the conditions should be met. In eliminating the candle power bogie, the adaptability of coke ovens will become so apparent that their use will be universal.

With the ever-increasing price of crude oil and the ever-increasing demand for a lower-priced gas, there can be but one answer,—a cheaper form of production.

One of the latest questions to be raised against the use of by-product coke ovens by commercially-interested parties, is that the manufacture of illuminating gas from by-product coke ovens will in a comparatively few years seriously affect the by-product market and the coke market. Nothing could be more incorrect. The substitution of by-product coke ovens for gas retorts would increase the ammonia yield to some extent, and decrease the tar production. In other words, the effect on the yield of by-products would not be sufficiently great to interfere with the steadily increasing demand for these products, and would not affect their price one iota.

With regard to the effect on the coke market, there is at present about 200,000,000,000 cu. ft. of illuminating gas manufactured in the United States per annum, at least that amount of gas is sold for illuminating or other domestic purposes; it makes no difference what it is used for; that is the amount of gas that is being manufactured. Now, if every cubic foot of this gas was manufactured in by-product coke ovens on coals averaging 10,000 cu. ft. of gas per ton (provided the ovens were operated on producer gas, previously cleaned, and from which the ammonia had been recovered and this gas regenerated), the amount of coke thrown on the market from such a production would not amount to 50% of the coke consumed in the production of pig iron alone. Not only this, but the greatest field for the use of coke has not yet been touched.

I think we can, therefore, dismiss any statement that deprecates the adaptability of the by-product coke oven to the manufacture of illuminating gas or, as a matter of fact, to the production of gas used for any purpose whatsover.

RECOVERY OF BENZOL.

Before leaving this subject, I will refer again to the recovery of benzol. This is an enormous industry in Europe. There is not a motor car in Paris or Berlin that does not use benzol for power. Today practically the entire amount of it recovered in the United States is used for enriching illuminating gas. Remove the candle power factor and this benzol will be thrown upon the market. We all know that the price of gasoline is increasing, and every man who runs an automobile or an auto-truck will welcome any fuel that is equally as satisfactory, at a slightly reduced price. There is a demand for such a commodity and we have no supply. Benzol is 10% to 15% higher in efficiency than gasoline, and, contrary to popular opinion, it can be burned in any carburettor that will consume gasoline.

The average coking coal yields from 1½ to 2 gallons of benzol per ton of coal carbonized. Placing a value of 10c per gallon on this, it is unnecessary to go further into the advantages to be gained from the recovery of this product.

RELATION OF BY-PRODUCT COKE OVEN TO THE COAL INDUSTRY.

The coal production in the United States for 1912 amounted to 500,000,000 tons. Its estimated value was approximately $700,000,000, the record so far for any single year, and it was about one-half the world's production. The growth of the industry is shown below:

In	1850	11	states	produced	7,018,181	short	tons.
"	1860	15	"	"	14,610,042	"	"
"	1870	21	"	"	33,035,580	"	"
"	1880	25	"	"	71,481,570	"	"
"	1890	28	"	"	157,770,963	"	"
"	1900	28	"	"	269,684,027	"	"
"	1910	27	"	"	492,647,863	"	"
"	1912	28	"	"	511,964,403	"	"

The output has doubled every ten years. The production of coke in 1912 amounted to 43,000,000 tons only and was, as shown, practically all consumed for metallurgical purposes.

In a comparatively few years the combustion of soft coal will not be permitted in the big centers. How would such an ordinance affect New York and Chicago as an example?

No definite statistics are available for New York, but it is conservatively estimated that the amount handled is 32,000,000 tons per year. Because of the smoke restrictions in effect, the consumption of soft coal is less than 5,000,000 tons per year. It is estimated that over 12,000,000 tons of anthracite are consumed in New York proper.

Chicago handles over 21,000,000 tons of coal per year, principally soft coal.

The State of Illinois produced over 50,000,000 tons of coal in 1912.

The railroads consume, within the city limits, over 5,000,000 tons of coal per year.

These conditions apply to other big centers in proper ratio.

It is easy to imagine the replacement of soft coal in these centers, and they would support several plants the size of that at Gary in any one locality. When consumers learn that coke is not only the cleanest possible kind of fuel but the cheapest, its use will be universal.

Furthermore, all students of economy are unanimous in stating that the use of coal in crude form for any purpose whatsoever is an economic crime. There is no purpose for which coal is used today but what the same amount of work can be performed with the same cost or less with coke. Political economy teaches that there is no source of real wealth other than land and labor and one of the most priceless possessions we have is our coal supply. If you consider an average value of 50c for the by-product that can be recovered from a ton of the average coal, there is $250,000,000 in pure wealth destroyed annually at our present rate of consumption.

To sum up, there is no doubt that natural development will take care of the present reckless extravagance in the use of our raw material. It is also perfectly obvious that this will have to be followed along sane and reasonable lines, but without any unnecessary lapse of time. Statistics have shown that 75% of the total coke produced is made in ovens of the non-recovery type. These plants represent a vast amount of capital, and the present locations of the blast furnaces are such that it is questionable, even when taking into consideration the tremendous saving to be obtained from the modern process of coking, whether such plants could be commercially profitable in certain localities.

About 40% of the total freight revenues of the railroads is derived from the transportation of coal and coke. This freight tariff plays an important part in the location of a by-product coke plant. In other words, every locality has its average price for coke and this price will vary as the distance from the source of supply. It is, therefore, obvious that if no coals are available other than those at present supplied for use in the production of coke, the situation becomes one of purely commercial reasoning, whether the amount of money saved in the price of coke per ton would pay for the investment required. But suppose there are coal fields available with a considerably reduced freight rate: the question then is not one of returns on the investment, but on how fast the plant can be built, because the coke could be produced at a price that would absolutely exclude any product that had a less favorable freight rate.

The smallest unit of by-product coke oven that can be constructed with any degree of commercial success will cost, roughly, $1,000,000, hence it is obvious that the proposition must be studied very carefully from all angles and reduced to its final terms; its installation will depend entirely on its location.

With reference to the relationship of the market for by-products to the coke industry, I am informed that a market is absolutely assured as long as the industry develops in a sane and reasonable way. I have been furnished with data and pictures from the American Coal Products Company which will illustrate the enormous advantage to be gained by the farmers from the use of ammonium sulphate, and I desire to express my thanks to that company for their courtesy and interest in this matter.

You are referred to a paper which was read by Mr. W. N. McIlravy before the American Gas Institute in 1911. It describes the status of the by-product industry to date.

I feel sure that we can depend upon natural conditions, natural growth, and natural conservatism to create the demand for by-product coke ovens. In order to place the industry in its proper position, it is necessary to educate those who are not familiar with the subject; to give them plain, simple facts. Unfortunately the business in the past has been shrouded in mystery and a mass of technicalities. It is not a simple art. It is a fact that intelligent skilled labor and well-trained minds are required to properly and successfully carry out the policy of a coke plant and develop it to its utmost capacity. But the bulk of the actual work is performed by common labor and there is nothing about it that is in any way more complicated than the operation of a modern blast furnace or an open hearth steel plant. The success of the plant, of course, depends on experience. The plant policies must be carried out by men trained for the purpose, and it takes a long time to acquire the necessary experience to formulate and to carry out these policies, but we have enough material in the country to draw from. Our universities are sending out such men, and after a certain amount of training at a small expenditure of capital, they develop into suitable material for whatever needs may arise. The field of by-product coke manufacture is one of the most promising industries, and I would like to urge upon those directly or indirectly interested, to encourage men of the right kind to enter that field.

OPERATION OF A MODERN COKE PLANT.

Following is a description of the operation of one of the most modern coke plants in the world. This plant carbonizes about 10,000 tons of coal per day. The entire amount of coke produced is used in the manufacture of pig iron. The surplus gas produced is consumed in the different parts of the adjacent steel mill.

The coal mixture used at this plant is 80% Pocahontas and 20% high volatile from the Pittsburg district. The coal is brought by rail into the plant and unloaded into receiving track hoppers. From there it is conveyed by belt conveyors to the coal crushing building. Here the coal is first passed through Bradford breakers, where the impurities such as slate or pieces of wood, draw-bars or coupling pins, in fact refuse of any character, are ejected from the breakers; the good coal is broken and passed through the openings in the screens.

A Bradford breaker is simply a cylindrical screen with holes of suitable diameter, usually about 1½ in. to 2 in. It is equipped with shelves which carry the coal in the direction of the travel of the machine. When it reaches the top it drops on a plate. Naturally anything soft enough to break into a size sufficiently small will pass through the openings so that the slate is not entirely ejected. It is a very efficient method of separating foreign matter from the coal.

After the coal has passed the Bradford breakers, it is conveyed to the pulverizers. Before entering the pulverizers it passes over a suitable apparatus designated as a magnetic separator, where the smaller pieces of iron are removed. This apparatus consists usually of a magnetized pulley over which the conveyor belt travels, or a magnetized plate over which the coal is allowed to slide. The plate being centrally pivoted it can be swung out at stated intervals and the scrap iron recovered.

There are several kinds of pulverizing machines. They are all operated on the same principle. One of the most efficient is the so-called Hammer Mill, which consists of a series of hammers supported by suspension bars. The shaft operating these hammers is directly connected to a suitable sized motor and travels at the rate of 500 to 600 r. p. m., a very rapid rate. The coal is fed in comparatively thin layers over an adjustable screen with perforations of the desired degree of fineness. The impact of the hammers on this layer of coal pulverizes and forces the coal through the screen. The plant described crushes the coal to a fineness of about 85% through a ⅛ in. mesh. Coals have varying degrees of hardness and it is necessary to make separate adjustments for each kind of coal. Therefore the apparatus necessary for the preparation of coal is divided to avoid continuous adjustments.

After the coal has been pulverized it is conveyed to a mixing bin. This bin is a double compartment from where the coal is fed onto separate conveying belts and conveyed to a point immediately over the mixers, where the coal is mixed in the different proportions desired. Since both of the conveyor belts to the mixing machine are traveling at the same rate of speed, having the same carrying capacity per unit of time, it is simply a question of adjusting the depth of feed on the belt in order to arrive at a reasonable degree of accuracy in the ultimate mixture.

From the mixing bin the coal is conveyed to the storage bins at the battery. The storage bins are usually so constructed that they have a 24-hour supply for the entire plant. It is customary to do all the crushing by day so that proper inspection and repairs may be made on the coal-handling equipment by night. As a modern coke plant operates continuously 24 hours per day, this question of coal supply is a very important one.

From the coal storage bins at the ovens the coal is charged into larry cars, which operate on tracks extending the entire length of the battery. It is unnecessary to say that they are operated electrically, as every part of the apparatus of the plant is so operated wherever possible.

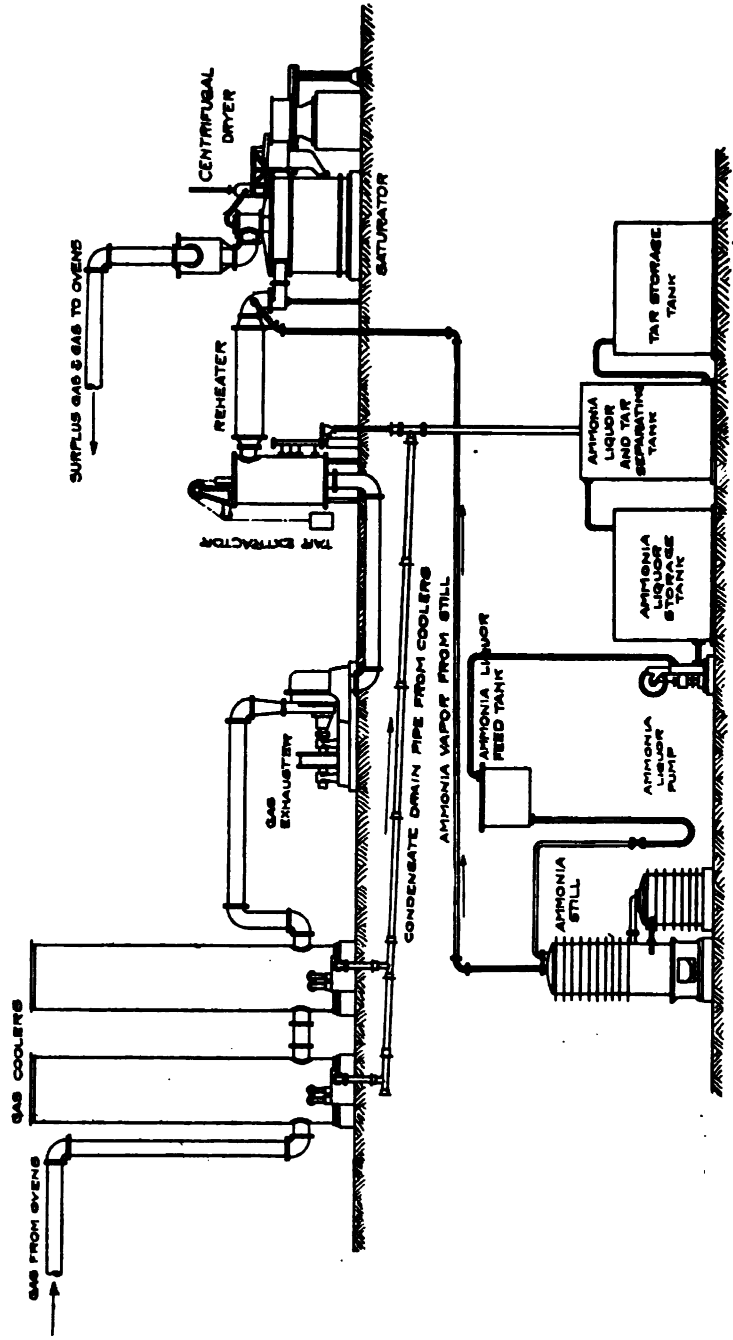
The coal is discharged from the larry cars into the ovens, where it is leveled to permit of a free path of travel for the gas evolved during the process of coking. From the time the oven is sealed, the charge remains undisturbed until it is ready to push out.

The process of coking consists merely in driving off the volatile matter in the coal by means of heat radiation from the heated oven walls. It is purely a process of distillation. Therefore, coke is the solid residuum and consists of approximately 90% carbon, the balance being the ash with such impurities as sulphur and phosphorus. The amount of ash and other impurities in the coke depends entirely on the amount in the coal used, as these substances remain in the residue from distillation. It is scarcely possible to eliminate all of the volatile matter, and usually 1% to 1½% remains, which is in the form of heavy tarry compounds of a fatty character, not easily driven off. When the volatile matter has been practically eliminated, which is usually accomplished in from 16 to 18 hours, the oven is ready to push. The doors are removed and an electrically operated pusher machine takes its place in front of the oven; the ram is carefully set in position against the face of the coke mass and propelled through the oven. The coke is discharged through the other end of the oven into a receiving car, which conveys the coke to the quenching station, where the coke is quenched by means of water. The coke is then screened; the object of screening being to free the coke from the fine dust or breeze, usually about 3%. Everything that goes over ¾ in. is considered suitable for the blast furnaces. There is also an appreciable increase in yield of combustible matter due to the breaking up of the tar vapors in the passage of the combustible matter through the heated mass of coke. But practically speaking, the fuel value of the coke is in direct proportion to the fuel value of the coal entering into its production.

We will now follow the gas as it is evolved from the coal. As previously stated, the coal is leveled to allow the gas a free path to the offtake pipe, which is situated at the end of the oven. The gas ascends this offtake pipe into a so-called collecting main and from there travels by means of mains to the condensing house. The gases leaving the oven chamber are about 1000 deg. F., and this temperature is gradually reduced to about 200 deg. The reduction in temperature precipitates the bulk of the condensate from the gases. This condensate consists of tar, oils, and the moisture originally in the coal and the amount formed during the process of coking, and drains into settling pans or tanks, where, owing to the difference in specific gravities, the separation is easily carried out. The water is slightly impregnated with ammonia and is usually known as weak liquor to differentiate it from the strong ammonia liquor which is produced in another phase of the operation. The tar, after undergoing a period of decantation, is shipped in tank cars.

We will now follow the gas which passes through the by-product recovery house. Fig. 1 illustrates the various steps described below. The gas still contains traces of tar and water vapor, and in order to remove these elements the gas is passed through the primary coolers. The coolers are rectangular in shape and consist of a series of standard steel boiler tubes through which water is constantly flowing and around which the gas traverses. The whole operation is on the counter-current principle. The gas then enters the exhausters. These can be of either the positive displacement type electrically-operated or the modern turbo type. Up to this point the gas has been under suction, the amount of suction depending on the distance the gas is drawn from the ovens. The controlling factor in the operation of the exhauster is the pressure desired at the ovens. It is usually considered good practice to operate as nearly as possible to zero within the oven chamber, or at any rate not more than ½ mm. to 1 mm. back pressure.

From the exhausters the gas under pressure is forced through tar extractors to remove the final traces of tar. The tar extractor is a very ingenious piece of apparatus, consisting of a so-called



PROCESS FOR THE DIRECT RECOVERY OF AMMONIUM SULPHATE, KOPPERS' PATENT.

Fig. 1.

basket made up of sections of thin plates perforated and set up in such a way that the perforations are staggered. After the gas has been forced through the perforations it is usually quite free from tar. The principle is very simple. As the gas is forced through a perforation it impinges on the solid section of the plate ahead so that any liquid globules are arrested, broken up, and trickle down the surface of the plate. The gas after passing through the basket is forced through the reheater, which is similar in design and principle to the coolers, but instead of water passing through the tubes, live steam is used. The gas, after being reheated to a temperature of 50 deg. C., passes into the saturators, containing a saturated solution of ammonium sulphate and about 5% of sulphuric acid. The reaction and precipitation is almost instantaneous. The salt is ejected and allowed to drain; then it is centrifuged and conveyed into the storage house where it is ready for shipment—usually in sacks of 200 lb. bulk. The sulphate received from this process is perfectly white and contains at least 25% of ammonia and only 0.1% to 0.2% of sulphuric acid. The weak liquor previously mentioned is distilled and the ammonia vapor is directed to the header in front of the saturators where it mingles with the gas. In this way the entire recovery is complete.

This process has many advantages, among which are:

1. Extreme simplicity.
2. Small amount of space required.
3. Ammonia washers unnecessary.
4. Less pumping capacity required.
5. Less steam consumption.
6. A higher degree of ammonia recovery.
7. Can be installed in any climate because independent of temperatures of water supply.

We have now covered the coke, tar and ammonia. It remains to briefly mention the gas.

By-product coke oven gas has an average heating value of from 450 to 600 B. t. u. per cu. ft. This is a wide latitude, but the character of coals we have to deal with and the different purposes for which the gas is used, allows the production of gas within the range of these figures. The average coking coal will produce about 10,000 to 11,000 cu. ft. of gas per ton of coal. About 50% of this is required for combustion at the ovens to carry out the coking process. The balance is considered surplus gas, and can be used either for illuminating purposes or for replacing other forms of fuel. One of its principal uses in steel mills is the replacement of coal under boilers for the generation of steam power. In Germany it is used extensively in open-hearth furnaces and this practice is in evidence in this country to a small extent. In Germany it is considered the best kind of fuel for open-hearth furnaces, on account of the higher temperatures obtainable, better economy both in the use of heat and in the construction of the furnace, increased tonnage, and lower operating costs as compared with producer gas. The gas was first used in the same manner as producer gas, being regenerated before reaching the combustion chamber. This was found unsatisfactory and is unnecessary as its high heating value enables sufficiently high temperatures to be maintained without regeneration. It was proved that the gas lost approximately 9% of its heating value by preheating. This would depend to a very great extent on the character of the gas regenerated.

However, the gas is now used cold and only the air is regenerated, which allows smaller regenerating capacity and cheapens furnace construction. On account of the high heating value of coke-oven gas, a temperature may be maintained considerably higher than with producer gas, allowing a greater tonnage for the furnace. The output in some cases has been known to increase from 15% to 20%..

Some of the objections to the use of by-product coke oven gas in open-hearth furnaces are that it shortens the life of the furnace; and that the gas has a tendency to rise and burn along the roof of the furnace instead of immediately over the metallic bath. These difficulties are merely mechanical and obviously can be overcome. We have information where the roof of a furnace has actually stood more heat than with producer gas, while the life of the checkers was greatly increased. The efficiency in the use of producer gas will increase as the workmen become better acquainted with its different characteristics. Its value as a fuel will depend on the locality and the nature of the fuel it is replacing. Its minimum value is when it replaces coal under boilers; its value increases when used to replace crude oil; and its maximum value is when used for illuminating purposes. In other words, the value of the gas is strictly one of utility and will vary under varying conditions.

The average coking coal will yield from 5 to 7 pounds of ammonia and from 6 to 10 gallons of tar. It is the recovery of these by-products and their steadily increasing value that makes the by-product coke oven possible.

KOPPERS' CROSS REGENERATIVE BY-PRODUCT COKE OVENS.

A battery of Koppers' ovens consists mainly of a series of hollow walls, built of the finest silica material—really silica beams resting on foundations extending to rock or some equally satisfactory bearing material. The space between the walls is divided horizontally into two compartments, the upper forming the coking chamber and the lower the regenerators. Figure 2 shows the relative position of the regenerators to the oven chamber and the direct connection of the regenerators to the heating flues.

The hollow walls forming the coking chamber are constructed to form a series of vertical flues opening into one common horizontal flue, extending the entire length of the wall. (See *G*, Fig.

3.) It is in these flues that combustion takes place and the heat transmitted through the material of the walls into the coal mass.

The coking chamber is sealed at either end by heavy iron and steel doors, either of the self-sealing type or of the plug type, resting against the wall jambs and sealed with luting clay. Each door on the pusher side is equipped with a small self-sealing door large enough to permit a traveling bar to enter for the purpose of leveling the surface of the coal charge so that the gases evolved during the coking process may have a free and uninterrupted path to the offtake usually located at the end of the oven, and through which they are drawn to the by-product recovery plant.

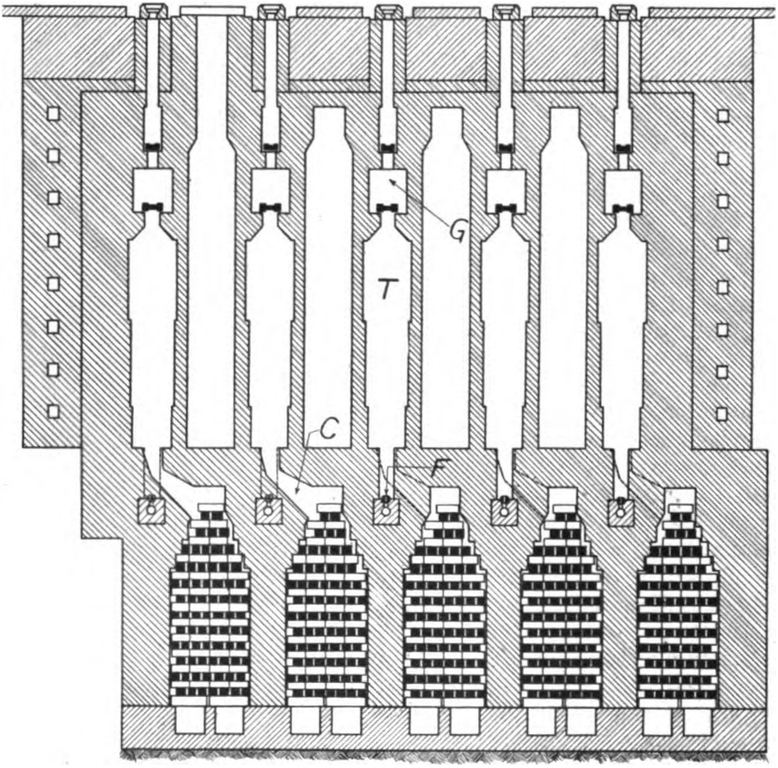


Fig. 2.—Showing Cross Section of Regenerators and Ovens.

The coal is charged from larry cars through openings or charging holes in the roof, usually four in number, equipped with self-sealing covers.

Figures 3 and 4 show a longitudinal section of the oven cham-

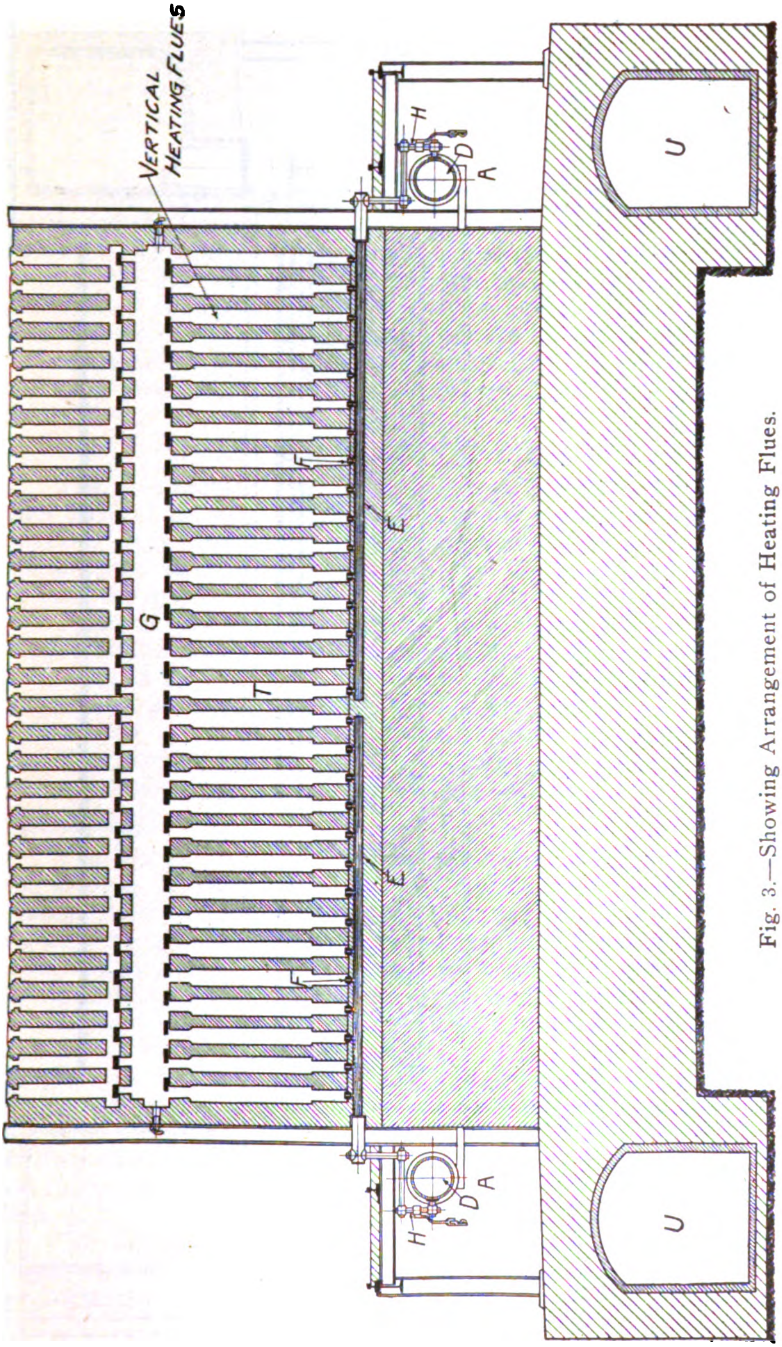


Fig. 3.—Showing Arrangement of Heating Flues.

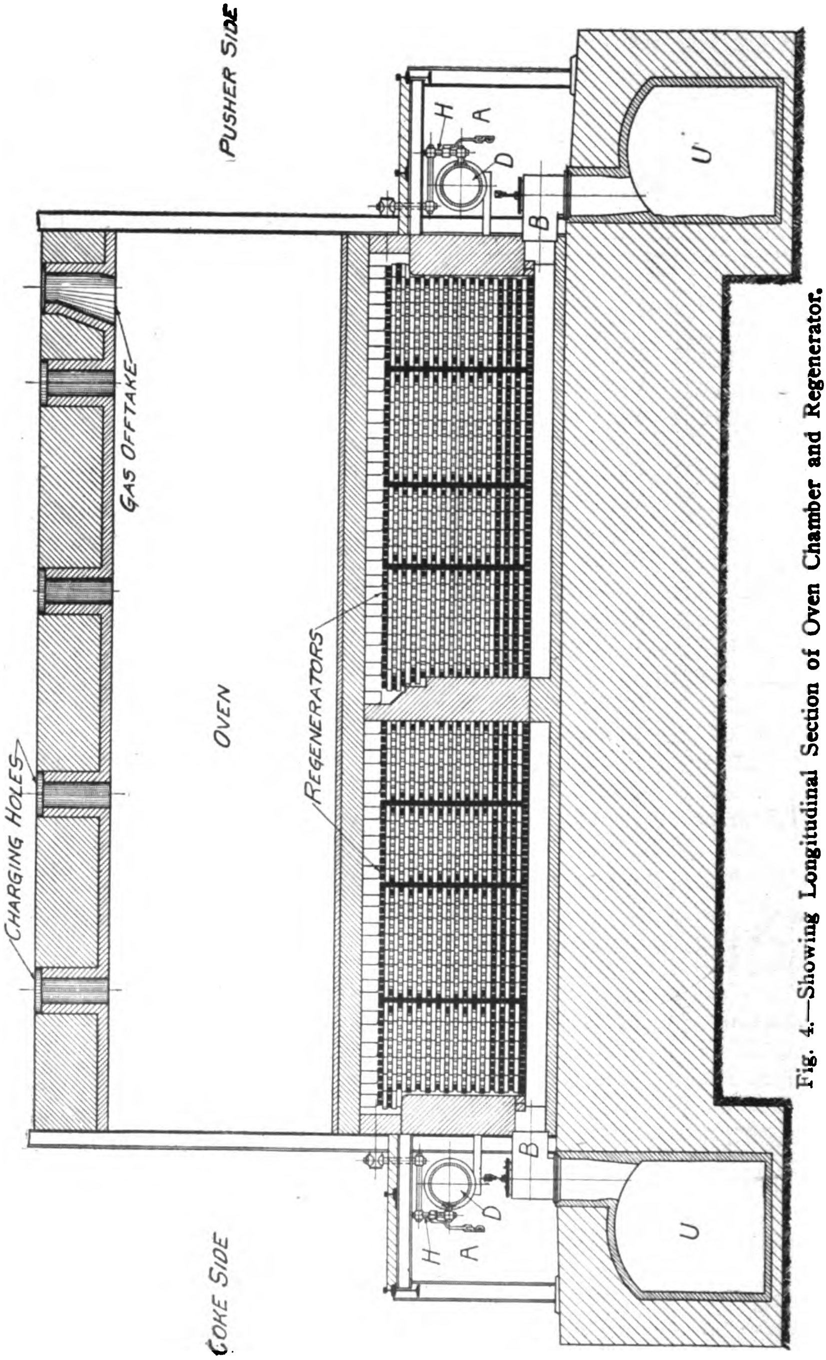


Fig. 4.—Showing Longitudinal Section of Oven Chamber and Regenerator.

ber, regenerators, and heating flues, as well as the position of the charging holes and the gas offtakes.

It will be seen from the above that the process of coking in a by-product oven is merely one of distillation carried on in a chamber from which air is excluded.

COURSE OF COMBUSTION.

A line drawn vertically through the center of a longitudinal section of the heating flues and regenerators (Fig. 3), will enable the course of combustion to be easily followed. Combustion takes place in the flues on one side of this line and proceeds upward; the products of combustion travel across the horizontal flue *G*, Fig. 3, and downward through the set of flues on the other side, through the regenerators (Fig. 4) and to the stack. The process is automatically reversed at periodic intervals usually of 30 minutes' duration.

CHARACTER OF GAS REQUIRED FOR HEATING.

The heat required to coke a given unit of coal is generally less than 50% of the total thermal value of the gas evolved by its distillation. It is customary to use the required amount of oven gas for this purpose after it has been freed from the by-products. It may be that this gas has such a value that it is desirable to render the entire amount of coal gas available for sale, in which case combustion in the oven flues can be maintained by the use of a cheaper fuel, such as the gas from producers operating on a lower grade of coal; or, as in some cases, blast furnace gas is used.

METHOD OF DISTRIBUTION AND REGULATION OF COMBUSTION.

The manner in which combustion takes place, its distribution and regulation, can be seen by referring to Figs. 2, 3 and 4.

Distribution:

The fuel gas is delivered to the battery in the main *D* (Fig. 4), and ascends the riser pipe *H* into the gas channel *E* (Fig. 3). This channel is located immediately under the vertical flues and extends the entire length of the ovens, being dead-ended in the center. It is formed by a series of bricks of special shape, making an absolutely air-tight duct. At the base of each flue is an opening in which the gas nozzle *F* rests, and through which the gas flows from the gas duct into the flue for combustion.

The air for combusion is drawn into the chamber at the base of the regenerator, ascends through the checker work, and is raised to a temperature probably around 1800 deg. F. This highly heated air then passes through the ports *C* (Fig. 2) at the base of each flue and mixes with the gas at a point about level with the floor of the oven.

The burning gases ascend the set of flues on one-half the length of the oven, the products of combustion follow the path of the horizontal flue *G* and pass downward through the vertical flues on the other half, through the ports *C*, Fig. 2, through the checker work into the chamber at the base of the regenerators, and thence by the stack flue *U* to the stack.

It will be seen from the above that each wall is a separate heating unit, having its own gas and air supply. It also has its own regenerator, which is directly connected to the stack and is equipped with a regulating device so that the stack draft can be regulated at will.

It then follows that in order to have the same heating conditions for each oven, all that is necessary is to maintain a uniform supply of gas in the mains *D* and the same amount of stack pull at the base of each regenerator outlet into the stack flues *U* (Fig. 3).

The individual cross-regenerator permits a much greater capacity than the longitudinal. The Koppers' individual regenerator has a capacity four times greater than that in general use in other types. The protected location of this type of regenerator makes the substructure simple in character, much less liable to expansion defects, and permits of less radiation. The individual regenerator is an essential feature of the Koppers' system.

Regulation of Combustion:

We have followed the course and distribution of combustion and it remains to show the method of heat regulation. It is this particular feature of the Koppers' ovens on which we desire to lay stress. When an oven is charged, we have a long, narrow, rectangular mass of coal about 35 ft. long, 9 ft. high, and 19 in. in width exposed to the surface of a highly heated wall on both sides. These walls are made up of 30 flues in which continuous combustion is carried on.

The object is primarily to transmit the required amount of heat into the coal so that the entire mass will coke uniformly and in the shortest space of time.

Eliminating all refinements, the chief factors are:

The rate at which coal will absorb heat.

The rate and intensity at which combustion can be maintained.

The amount of heat generated that can be transmitted through the oven wall into the coal.

The product of the above means the shortest possible coking time and maximum tonnage.

Before the above equation can be balanced, we must insure a ***uniform transmission*** of heat over the entire surface of the coal exposed to the heating action of the walls. In order to do this, we must maintain a uniform intensity of combustion throughout the entire length and height of the heating flues that form the oven walls. To maintain such an ideal condition, we must have control over every square foot of heating surface, and in order to have this control, there must be *accessibility* to every part of the heating system; not only up to the oven itself, but including the oven proper.

We have shown that the first step necessary is to be assured that each oven has exactly the same capacity for combustion. Each oven must have the same supply of air and gas, and the products of combustion must be drawn away at a uniform rate.

The Koppers' oven generally depends on natural draft for supplying the air for combustion and for drawing away products of combustion. The flue dampers and air valves control the rate at which these functions are performed. It is obvious that up to this point everything is accessible and under positive control.

The regulation of the combustion in the heating flues is carried out in the following manner:

Reference to Fig. 5 will show that there is an opening extending through the roof construction into each flue. In fact, this opening is a continuation of the flue proper, but is closed by means of the cover brick described later. The removal of the cast-iron cover from this opening exposes the entire surface of the exterior of the flue for inspection. In this manner observation of the combustion taking place throughout the entire length of the oven is made easy. The gas opening at the base of each flue is equipped with a nozzle having a definite size opening so that it is possible to increase or diminish the amount of gas admitted to each flue. Alongside this nozzle is the air port. These ports are all calculated for an excess air supply, but they bear an exact relationship to the area of the vertical flues. It is then only a question of regulating the amount of air drawn into each flue and fitting the opening at the base of the flue into the gas duct with the proper size gas nozzle in order to ob-

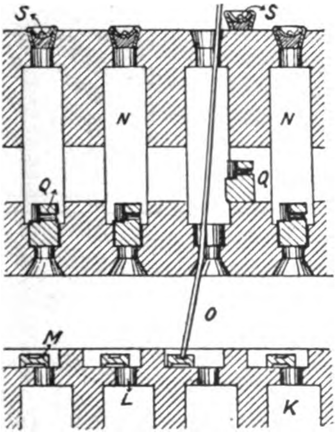


FIGURE 5

tain precise intensity of combustion desired. Reference to Fig. 5 will show how this is accomplished. It will be seen that at the bottom of the horizontal chamber *O* is an opening covered by a sliding brick *M*. This sliding brick is an adjustable damper controlling the amount of draft for each flue.

A little farther up in the chamber will be seen another opening which is completely closed by a cover brick *Q*, except during inspection and regulation. The opening is finally closed on the top of the battery by the lid *S*; by taking off this lid *S* and sliding back the intermediate cover brick *Q*, an unrestricted view is obtained of the interior of the vertical flue. It is a simple matter to adjust the sliding brick damper *M* to the extent desired in order to obtain any intensity of combustion. That is the only practical way to decide on the amount of air required for each particular flue. Assuming that a local over-heating occurs in any part of the oven wall, it is simply a question of opening up those particular flues, taking the nozzles out and putting in a smaller size, or vice versa. by means of the rod shown in Fig. 6. Once a regulation has been made for an entire oven or for any number of ovens, it is not necessary to interfere with the regulation until the entire general conditions require changing. Once a regulation for any definite coking time is established, it is simply a question of raising or lowering the gas pressure, increasing or diminishing the stack draft. The value of the accessible flue is then not only that of inspection but also of regulation.

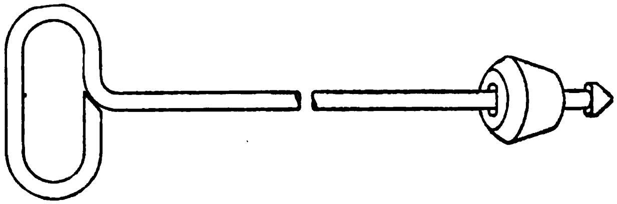


FIGURE 6

Showing Gas Nozzle and Rod for Removing Nozzle

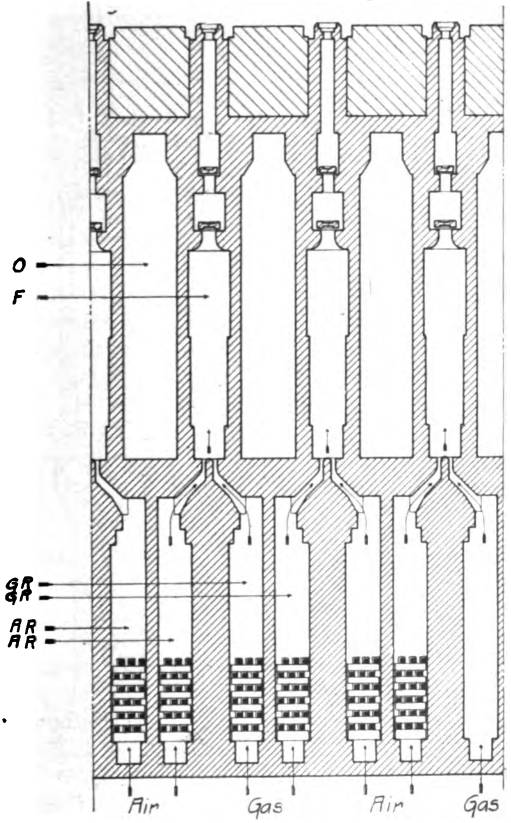
If an oven charge is pushed and the coke is not perfectly uniform throughout, it must be evident that to be able to inspect and correct conditions for that particular oven, is a big advantage. The ability to positively control the rate of coking means that the maximum efficiency can be maintained as regards output per battery, and this efficiency can be expressed in dollars and cents.

KOPPERS' REGENERATIVE GAS CHAMBER OVEN.

Reference to Fig. 7 will show that the construction of the gas chamber oven is merely a modification of the regenerative coke oven.

Combustion in coke ovens is usually carried on by utilizing part of the oven gas after being freed from by-products. As stated, this requires about 50% of the total gas evolved.

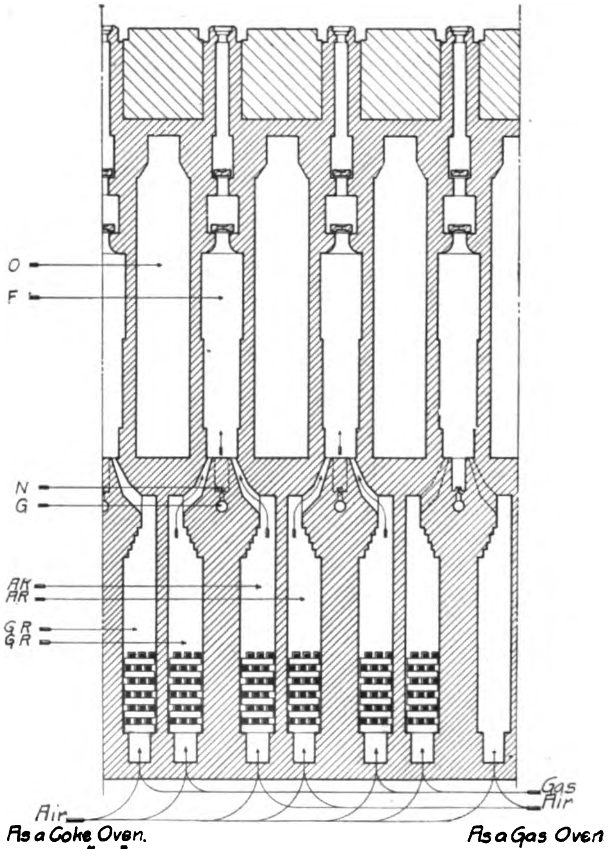
The prime object of a coke plant is to make coke with the recovery of as high a yield of by-products as is consistent with proper operation. In the gas oven the conditions are reversed. The prime object is to produce as high a yield of gas as possible and of the proper quality. It is undesirable to use any of the gas distilled from the coal for fuel. Its value is too high. It is, therefore, desirable to install a producer plant, using a low grade of fuel. The producer gas is cleaned, regenerated, and burned at the ovens to maintain the process of carbonization. It also may be advisable to recover the ammonia from the producer gas and in this way a very low cost fuel can be obtained.



"B" Koppers Cross Regenerative
Gas Oven

Fig. 7.

Reference to Fig. 7 will show the changes in construction. The regenerator chambers are subdivided by a partition wall with openings extending into the combustion flues as shown in the coke oven. Air and gas are regenerated in alternate sets of regenerators. For illustration, air would enter the passageways at the base of the regenerators, and the gas would enter the openings in the regenerator chamber. Air and gas follow the same direction, combustion following precisely the same course as in the coke oven. The advantage of dividing each regenerator into two sections and passing the same material through each regenerator, whether it be air or gas, lies in the fact that should the division walls develop leaks, no harm



"C" Koppers Cross Regenerative Combination Oven.

Fig. 8.

can be done as the material is precisely the same in each set of regenerators.

It will be noted that there is no fuel gas duct extending under the flues as in the coke oven. The producer gas is regenerated and enters the vertical flue through the openings or ports leading directly from the regenerator chamber into the flues.

KOPPERS' REGENERATIVE COMBINATION COKE AND GAS OVENS.

The Koppers' regenerative combination oven, Fig. 8, has been designed to act as a coke oven until such time as the demand for gas makes it advisable to operate as a gas oven.

The only difference between this oven and the gas oven is the addition of the gas distributing flue as shown in Fig. 8. This oven can be operated as a coke oven, the regenerators being used in the usual manner exclusively for air. Coal gas should never be regenerated.

When the demand for gas increases, the producer plant is installed and the ovens are then operated as gas ovens, using the producer gas as fuel. It is, of course, necessary that re-adjustment take place for any change in condition; that is to say, though the ovens can be operated as a gas or coke oven alternately, time must be allowed for adjusting to new conditions. It may be advisable, for instance, to operate as a gas oven in the winter and as a coke oven in the summer.

This type of oven is well adapted to localities where the present gas demand is equal to the surplus gas output of the battery and where future indications are that the demand will be doubled.

DISCUSSION.

W. L. Abbott, M. W. S. E.: There are present those who know more about gas and more about coke than I do, as I know very little about either, and so I feel quite incompetent to discuss those questions, but there occurred to me the possibilities of reducing some grades of our Illinois coals in gas producers for the sake of the by-products.

There is produced annually in the central western coal fields of Illinois and Indiana something like 75,000,000 tons of coal, and of this amount about one-tenth is of a size which will go through a ¼-in. round-hole screen. The remainder of the coal for whatever purpose used would be better and of more value if the very fine coal were taken out of it. This means that somewhere in the neighborhood of 7,000,000 tons of coal might be available at a very low price for reduction for the by-products alone, assuming that the coke were to be thrown away.

The content of nitrogen in the coking coals I understood to be about ten pounds to the ton, but the nitrogen in our western non-coking coals runs much higher than ten pounds to the ton. I presume it would run two or three times that amount, and is worth in compound about 15c per pound. That being the case, the ammonia which might be recovered from this coal dust should be worth perhaps as much as $4.00 per ton.

In addition to the ammonia recovered, there would be other by-products and gas which would also have a considerable value. This, then, opens up a field for the operation of a plant for recovery of by-products from a grade of coal which has no value as fuel and is a detriment to the fuel in which it is contained. It may be entirely impractical to handle such coal in a coke oven for the reason that the stuff will not coke, but the possibilities have always appealed to me, and I should be pleased to hear the subject discussed.

A. Bement, M. W. S. E.: The leading thought in my mind is the change the by-product oven has introduced into the iron and steel business. Formerly the furnace was located in the vicinity of the coal (Pennsylvania, very largely), rather than the ore, provided the latter could reach the furnace at a reasonable freight rate. The coke oven was in the country and in the woods where the coal was produced, and gas, which was not considered a by-product then, was a waste product as made in the beehive oven.

With the introduction of the by-product oven, making a salable gas provided there is a market, we have a changed condition, and the disposition of the gas is a matter of much importance. It can be used in engines, for firing boilers, soaking pits, in open-hearth and other furnaces; but its best market is for illuminating purposes. There it will bring the highest price. But to have such a market we must have a city. Therefore, the place for a blast furnace plant and steel works is in a large city, if we are going to get the best out of the by-product oven. In this way the steel plant contributes to the needs of and assists in the operation of the city. On the other hand, the utilities of the city may render service to the steel works. For illustration, if the gas is sold them, the plant will be short of fuel, to be made up by coal burned under boilers, in gas producers, or by the purchase of electric current, and it is in this way that the city renders service to the steel works. It was predicted some 15 years ago that the blast furnace might, in the vicinity of a city, supply gas engines generating electricity to supply the city and that iron would be a by-product. Such conditions, however, never worked out. With a steel works in connection with furnaces there is always use for all of the gas, but with merchant furnaces using gas power, or modern steam equipment, there is a surplus of furnace gas, which could be used to generate electricity. A populous community would be required, however, to furnish a market for the electricity and such a community would also ensure a market for gas. It would therefore be best to install coke ovens, and sell the gas from them, using furnace gas to heat them. The Gary works has an insufficient supply of gas, and is compelled to supplement its fuel supply by coal in gas producers. So it would be better to curtail the use of gas in engines and reserve it for heating, and buy sufficient electric current to make up the deficiency; this on the assumption, of course, that a central station service like that of ours in Illinois is available. Thus we find that instead of the blast furnace or steel works furnishing electric service, they are rather in a position to be served by the central station company.

I would ask the author what mixture is used at Joliet, also if there is any Illinois or Indiana coal used at the present time as a mixer.

Frank W. DeWolf, M. W. S. E.: My interest in this paper is chiefly because of my interest in Illinois coal, and I came here with the hope that something might be said of the possible future for Illinois coal in by-product-oven practice. I do not know of any topic of more interest to Illinois coal producers right now than that of the possibility of making coke and illuminating gas from our coal.

One of the chief reasons for this interest is the increased price of oil during the last year. You are, of course, aware that most of the gas plants of smaller towns make some coal-gas but a larger amount of water-gas which demands oil for enrichment. The price of crude oil in Illinois has doubled in the last twelve months, and there has been such an increase in the cost of oil for gas-house purposes that it is no longer economical to make water-gas.

This condition will have several results:

1. A return to the use of high-grade gas-coals in these small plants, at a considerable increase in cost.
2. An increased production of gas-house coke resulting from the use of this gas-coal.
3. Where the amount of service warrants, there will be installed central power plants and by-product-oven plants, with their high-pressure gas lines radiating for a hundred miles or more to adjoining towns, and with a very large quantity of coke thrown on the market.
4. There will be competition of the coke market with domestic fuels of the State and a lack of equilibrium in the coal trade.

The report has been for years, of course, that Illinois coal is non-coking, in spite of the fact that some domestic coke has been made in the southern part of the State, in Gallatin County, and that the same seam of coal produces considerable coke in western Kentucky. The tests of the United States Geological Survey at St. Louis on a dozen or more Illinois coals were successful but perhaps did not yield a commercial blast-furnace coke.

The question arises whether Illinois coal can be used in these new plants for gas and coke. During recent years experimenters have been working in an effort to use more and more of our Illinois coal in by-product coke ovens. I am told that it is common practice to use 10% of Ilinois coal. Sometimes 20% is used commercially, but hardly more than that. Yet I have seen this last year a large display of coke samples which are said to have been made out of 100% Illinois coal. I am not competent to judge of the structure of that coke for blast furnace purposes but it is promising, and so far as sulphur content is concerned, it seems feasible to get Illinois coal which will be satisfactory. I have also seen within recent months beehive coke made out of 100% Illinois coal, which was an eye-opener and seems to give great promise. In all these cases I understand Franklin County coal has been used most satisfactorily.

Professor Parr of the University of Illinois, who has been consulting chemist to the Geological Survey on some of these investigations, thinks he knows what ingredient causes the coking of coal, and he holds that any Illinois coal can be coked provided it is taken immediately after mining; but that this constituent of the coal which is the secret of its coking escapes during the first deterioration of the coal on exposure to the air.

I feel that the commercial demands of the situation, and the extreme activity of by-product oven inventors and experimenters, hold promise that in the course of the next five or ten years we shall have considerable use of Illinois coal in this process, for manufacture of gas and coke, and that we shall cease to have shipped into Illinois thousands of tons of eastern coal for this purpose.

Mr. Bement: Reference was made to domestic coke. The demand for blast furnace coke is limited, and it may be that considerable market can be developed for domestic coke to take the place of anthracite.

In line with what Mr. DeWolf has asked, it would be interesting if the author would say something about the possibility of coking Illinois coal and the manufacture of by-products from it. I would also like to know if there is any creosote oil manufactured in this country?

CLOSURE.

Mr. Kirkpatrick: With regard to the point raised by Mr. Abbott, the subject of the nitrogen content of Illinois coals is one to which I have given little attention, but I know that nitrogen content runs as low as 1¼% up to better than 1½%. What is known as the Mond process or a similar process could probably be used, and yield possibly 60 lb. of ammonia sulphate which is worth 3c per lb. on the market, or a little more.

Mr. Bement suggests that "the place for a blast furnace plant and steel works is in a city." So far as a blast furnace and its accompanying by-product coke plant are concerned, it probably does mean a large city or a place where the surplus gas from the coke plant can be disposed of; but when the coke plant is connected with the blast furnace plant and the steel mill, then we have a condition which is more or less self-contained. That is to say, the steel mill will draw on the surplus gas of the coke plant and make fairly beneficial use of it. At Gary, while there is some gas burning all the time at the bleeder, it is only on Sundays that there is any great waste. I might say the surplus gas burned at Gary is about

60,000,000 cu. ft. per day, and it is all used there mainly for heating purposes.

It is true that tar has been used successfully as open-hearth fuel. I am afraid, however, that the time is coming when the value of the tar will be too high for that use. We import upwards of 50,000,000 gallons of creosote oil per year, so there is a place to put our tar for some time to come. In this country creosote oil is manufactured by the American Coal Products Company.

Mr. Bement inquired regarding the mixture at Joliet and whether any Indiana or Illinois coals are used as a mixer. The mixtures at the Joliet steel plant have varied from 80% Pocahontas with 20% of high volatile coal (I believe what they call Klondike coal, giving an average volatile from 21½% to perhaps 22%) to 60% Pocahontas and 40% Klondike; or 60% Pocahontas, 20% Klondike, and 20% Illinois coal. I have no definite figures to give and do not know what the results have been. I know that they have used 20% Illinois coal with 20% Pittsburgh high volatile and 60% low volatile coal, and obtained good blast furnace coke. This Illinois coal I understand has been washed to get the best results. In a by-product coke oven plant, washed coal usually means a little larger yield of ammonia. I have no record of any Indiana coal being used.

Following along the line of the question of using Illinois coals, I regret to say that the company I am with did its development work in Germany; that is, we developed our oven on other coals than the coals of this country. Our first conditions here were to produce the blast furnace coke and when a result was reached that was satisfactory, we naturally kept rather close to that result. So our guarantees are usually based on a Pittsburgh and Pocahontas mixture, because we have that knowledge.

We have no experimental ovens; we have not built an experimental plant in this country; but we have put in one oven for experimental purposes in connection with the 65 ovens now being constructed for the Inland Steel Company, and we hope there to develop some information along the line of Illinois coal. There seems to be a general opinion that a good grade of domestic fuel can be produced from Illinois coals, but we are not ready now to give out any definite information on this subject.

It is stated, with reference to coal consumption in steel plants in Germany, that the only coal that was taken into the plant was that which went into the coke ovens; that the plants were operated entirely with the blast-furnace gas and coke-oven gas. We have not quite reached that condition in this country.

MODERATE CAPACITY OUTDOOR HIGH TENSION SUB-STATIONS

H. W. YOUNG, AFF. W. S. E.; ASSOC. A. I. E. E.

Presented at a Joint Meeting, Electrical Section W. S. E. and Chicago Section A. I. E. E., December 29, 1913.

The problem of furnishing electricity supply to isolated communities and consumers has received much attention during the past three years, and is now generally recognized as a serious and important undertaking, deserving the most careful consideration of central station managers. There never has been any question as to the desirability of giving service to outlying territories, providing the investment and maintenance charges were such that a fair return could be expected. Prior to the building of transmission networks and high tension distribution feeders radiating from a central point to smaller communities, the cost of lines to reach the small consumer, combined with the high cost per kilowatt of switching and protective equipment, practically closed a field now open to real commercial development.

The situation today, therefore, is vastly improved, as the consolidation and unification of central station systems has resulted in a large mileage of transmission lines passing through the districts ready and waiting for electrical development. The problem of supplying electrical energy to the rural districts is now rapidly forcing itself to the front as a real commercial and utility proposition, and the large number of isolated plants installed at high expense and operated under great disadvantage is an indication that the rural population is demanding and will secure electric service.

The idea is still prevalent among many central station managers that high tension distribution, in the ordinary sense of the word, will not pay. If the plan were to supply a single consumer or a small group at a considerable distance from the generating station, it must be admitted that such an opinion would be valid, but the supplying of current from high tension transmission systems is not going to be developed along such narrow lines.

The problem has resolved itself into the building of lines from a large-capacity centralized plant to a definite point where a load of suitable characteristics to justify the expense can be secured. From these high tension feeders branches will extend along the way, to farmers, mills, stone quarries, grain elevators, irrigation projects, railway pumping installations, dairy farms, canning factories, brick or tile plants, excavating shovels, etc.

SUPERSEDING OF SMALL GENERATING STATIONS

The small generating station supplying a town or village is necessarily at a distinct disadvantage in the generation and distribution of electricity as compared to the larger stations, as it is well recognized that the economy is low. This condition is due to the small amount of power generated, the poor load factor, and the fact that the size of the enterprise does not justify the employment of high class engineers or operators characteristic of the larger systems.

The small generating station will therefore be quite generally superseded by a sub-station, supplied from a high tension transmission line serving a number of communities. With one or more small towns as a nucleus, the transmission line is built,—the first step towards supplying an entire district or even county from a centralized plant. The supply of power along the main transmission lines then becomes a comparatively simple matter, and many possible installations heretofore considered undesirable come to the front as good commercial investments. In addition to supplying current to those who heretofore have been without its conveniences, the various isolated plants in a given territory will gradually be connected and tend to help raise the load factor of the entire system.

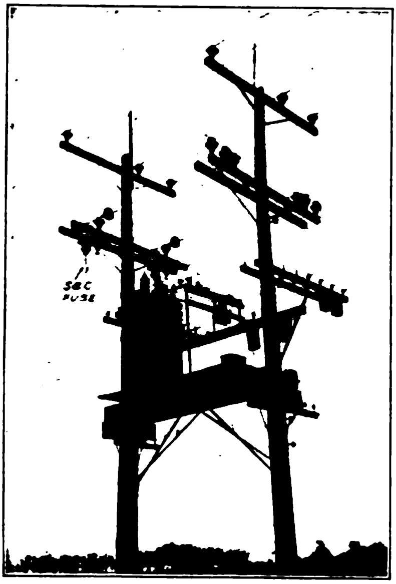


Fig. 1—33,000-Volt Single Phase Outdoor Substation

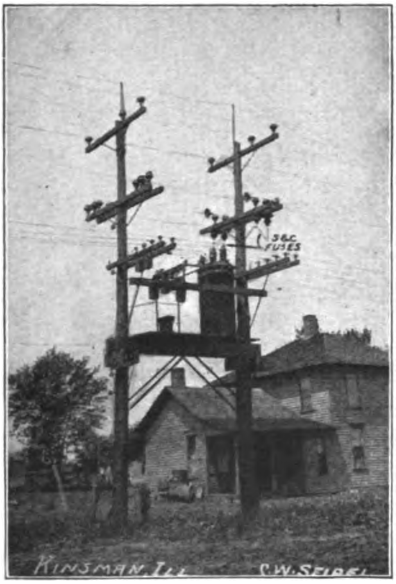


Fig. 2—33,000-Volt Station, Single Phase

The supply of electrical energy to the rural districts, especially in the middle-west states, therefore, is a most practical and attractive proposition, commanding the attention of many very able men who have the foresight to recognize the real possibilities. It is safe to say that, judging from present activities, the day is not far distant when a large majority of our small towns and rural population will have the same electrical conveniences as those heretofore almost exclusively enjoyed by dwellers in cities.

SECURING POWER LOADS

Another very important feature of high tension distribution is the fact that the possibiities of power loads are extremely good in what are now sparsely settled districts. With a network of high tension feeders covering the outlying districts, manufacturers seeking lower rents, taxes, labor, etc., will soon be attracted to the smaller communities where electric power is available. The question of extremely low rates for power will not be a serious one as the cost of power used in manufacturing is but a small percentage of the total manufacturing cost. The central station, therefore, will be able to secure a good return from this new class of consumers. If power is available where rents are low and expense less than in the cities, the manufacturers will inevitably move out, and this means an influx of new residents who will also require electric service.

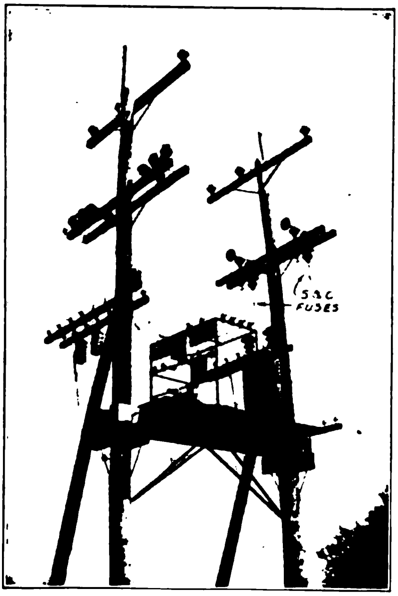


Fig. 3—33,000-Volt Station with Secondary Rack

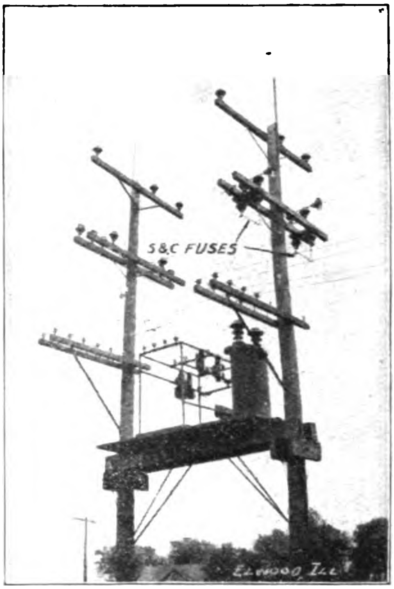


Fig. 4—Single Phase 33,000-Volt Station

With high tension feeder lines to definite points, the question of serving small communities or consumers along the lines becomes one of giving service at the least initial investment and maintenance cost. The outdoor sub-station then becomes the means of meeting the situation developed by consolidation or unification of plants and by the demand from our rural population for electric service.

HIGH COST OF SUB-STATIONS

A new situation now arises which is in a sense comparable with the problem presented by the small generating station. After installing some of the earlier types of high tension outdoor sub-stations employing expensive and more or less complicated equipment, it was soon found that in many instances the venture was bound to prove unprofitable as both the initial cost and maintenance were too high to insure a fair return on the investment. From a commercial standpoint, therefore, conditions were such that with a low generating cost at the main stations and an economical transmission system, the cost of local transformation and distribution was high and akin to that of the small generating stations which had been supplanted.

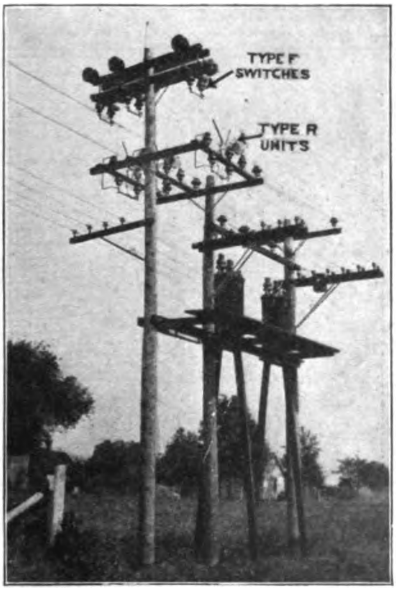


Fig. 5—22,000-Volt Station, Three Phase

The demand then arose for an entirely different type of outdoor sub-station equipment which would afford adequate control and protection at a reasonable cost per kilowatt. To meet the imposed conditions, many types of switches, fuses, and lightning arrester equipments were designed, all having more or less merit, and at the present time a very considerable number of these high tension equipments are in successful commercial service. Among the later and more modern types of equipment, the forms shown in the accompanying illustrations have been used to a considerable extent and their success is an indication that the problem of distribution from high tension feeders has been solved.

TYPES OF SUB-STATIONS.

During the past two years several distinct types of outdoor sub-stations have been developed and a large number are now in service. Some of the earlier small capacity types are shown in Figs. 1 to 4, inclusive, and are of very simple construction. The transformers are of the single phase weatherproof form mounted on a suitable platform supported by two standard poles; the lightning protective equipment consists of a pair of adjustable horn gaps set to "spill over" at approximately a predetermined value. Protection against overloads is secured by the use of special high tension fuses mounted either above or below the crossarms as desired, and when renewal becomes necessary a fuse can be removed and replaced by means of insulated tongs. The control switches are located on the next pole; in some cases these consist of a simple disconnecting type and in others a switch designed to open loaded circuits is used. An interesting feature of these stations is that the automatic street lighting regulators are also of the weatherproof type and are mounted near the main transformer.

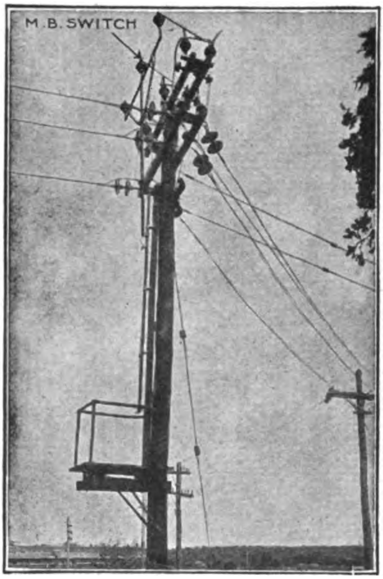


Fig. 6—22,000-Volt Pole Top Switch

The first stations erected were usually single phase for supplying street or commercial lighting, but the necessity for power service soon developed and the type shown in Fig. 5 was designed. This station is of 100 kw. capacity transforming from 22,000 to 2,200 volts; the secondary distribution is carried out in the usual manner, 2200/110/220 volt transformers being located near the consumer's premises. In the particular installation shown, the control switches are of the simple disconnecting type, but when conditions are such that opening the high tension circuit under load is necessary, the type of switch shown in Figs. 6 and 7 is extensively used.

Where the main transmission lines are adequately protected with lightning arresters located near the point where power is taken off, the installation shown in Fig. 8 can be used to good advantage. This installation is simply protected by means of weatherproof high tension fuses mounted directly above the transformers, the disconnecting switches being on the next pole.

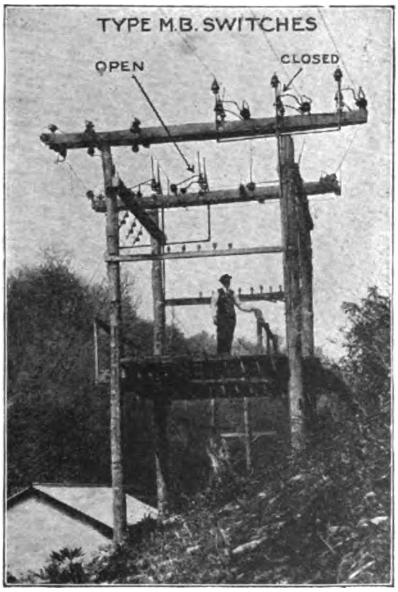


Fig. 7—Two 22,000-Volt Pole Top Switches

A second type of outdoor sub-station installation, where the entire transformers, switching, and protective equipment are mounted on the same structure, is shown in Figs. 9 and 10. The transformer is of the three phase type transforming from 33,000 volts to 2,200, the secondary distribution being of the usual type employing 2200/110/220 volt transformers. It will be noted that the three pole switch handle is located below the platform; the air break switch is opened before the linemen mount the platform, which increases the safety factor. Protection against overloads and lightning is secured by the use of high tension fuses, choke coils, and discharging horns. A small house is provided for secondary switches, meters, spare parts, etc.

A third type of three phase station is shown in Fig. 11 and is rather interesting in that it is designed to supply current for an entire town. This particular installation is of 300 kw. capacity and is located outside of an old steam plant which can be shut down at will; the sub-station can take current from the main lines, or the steam plant can be operated as an auxiliary feeding into the main line if it becomes necessary.

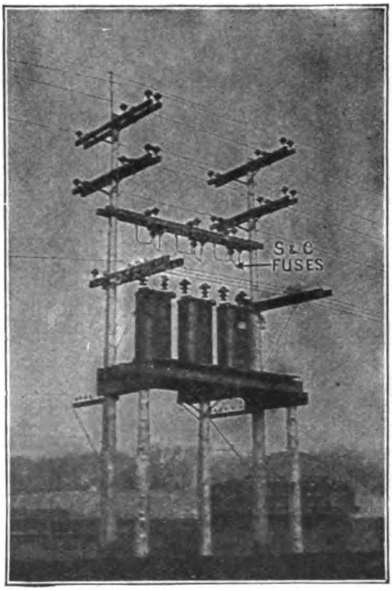


Fig. 8—33,000-Volt Station Fuse Protection Only

The 2,200 volt circuits are carried into the building at the left and distribution is made in the usual manner. With this arrangement the town can be supplied with current from the high tension 33,000 volt line, the local generating plant being shut down; or the local plant, can, when desired, be used as a generating point, feeding into the main line through the outdoor sub-station. This type of sub-station, using the old station as an auxiliary, offers a ready means of assisting in the unification of generating or distribution systems embracing a large territory or a number of towns.

A fourth type of high tension sub-station is shown in Fig. 12, and as will be noted the three phase air break switch is mounted on a separate pole adjacent to the three poles supporting the transformers, lightning arrester, and fuse equipment. This particular installation is connected to a 33,000 volt transmission system supplying power to a coal mine. Several of these stations are now in commercial operation and their operation under heavy sleet conditions will be watched with much interest. The switching equipment is so designed that it can be operated under severe sleet conditions, as in the particular territory where these stations are installed, sleet storms of great severity are quite common. The type of station shown in Fig. 13 employs the same form of switch as the preceding station. It will be noted that the fuse, lightning arrester, and transformer equipment are all concentrated at one point, thus giving a self-contained installation.

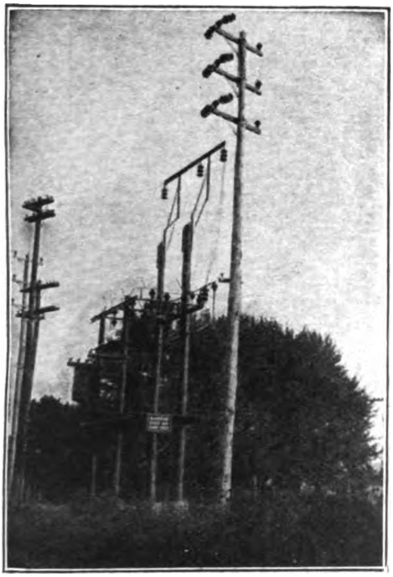


Fig. 9—Complete Station, High Tension Load Switching

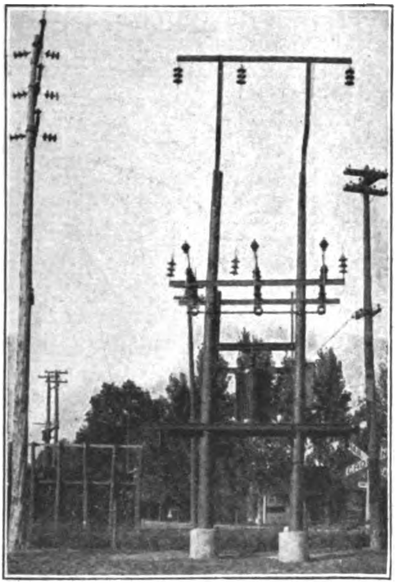


Fig. 10—Three Phase Transformer, 33,000-Volt Station

An interesting steel tower sub-station is shown in Fig. 14, a number of installations being in commercial service. It will be noted that the transformers and protective equipment are mounted on a common structure and the switch on a separate pole.

CONTINUITY OF SERVICE.

Anticipating the question as to the possibility of securing uninterrupted service, it can be said that absolute continuity of service cannot be guaranteed with any present type of outdoor sub-station equipment, nor is it expected, with the low-cost forms commercially available. With the latter types, in case of a heavy flow of current to ground, the protective fuse will perform its functions and rupture, thus cutting off the service. This condition must be admitted, but in a large percentage of cases an occasional interruption of outdoor sub-station service will not be considered serious or as a criticism of the service. It is obviously preferable to use this lower-cost switching and protective equipment, giving service which, while subject to an occasional interruption, insures a profit on the investment, than it is to use a higher-cost, more elaborate equipment, which, while it may insure fewer interruptions, will invariably render the venture unprofitable.

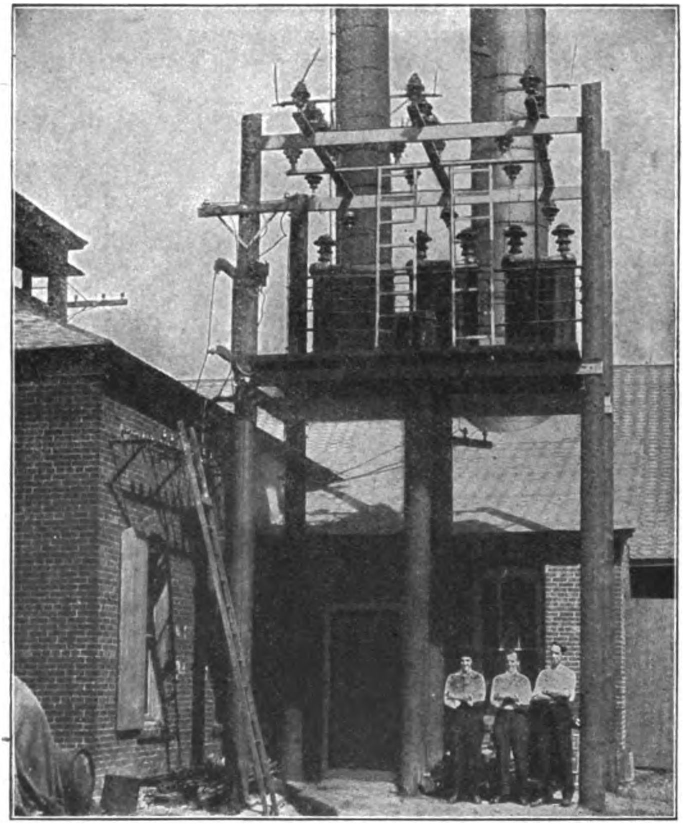


Fig. 11—300 kw. 33,000-Volt Station, Outside of Old Station

Primarily, the object of distributing high tension power is to make a profit for the central station, and it is daily being demonstrated that the simple outdoor sub-station equipments now being largely used are materially aiding in securing this profit. At this point a rather infrequent cause of interruption, as shown in Fig. 15, may be of interest. This rather indiscreet screech-owl caused a shut-down on a 33,000 volt feeder line, thus demonstrating the fact that high tension lines are not the proper place for even short visits.

Probably the most frequent cause of interruption on high tension systems is due to the failure of insulation; in other words, the line insulators used are frequently too light to meet those abnormal conditions which occasionally arise. The use of liberally designed insulators on the lines, the installation of electrolytic arresters at generating stations or important distribution points, and the frequent installation of air break sectionalizing switches, will materially aid in decreasing interruption to main lines or feeders. The outdoor

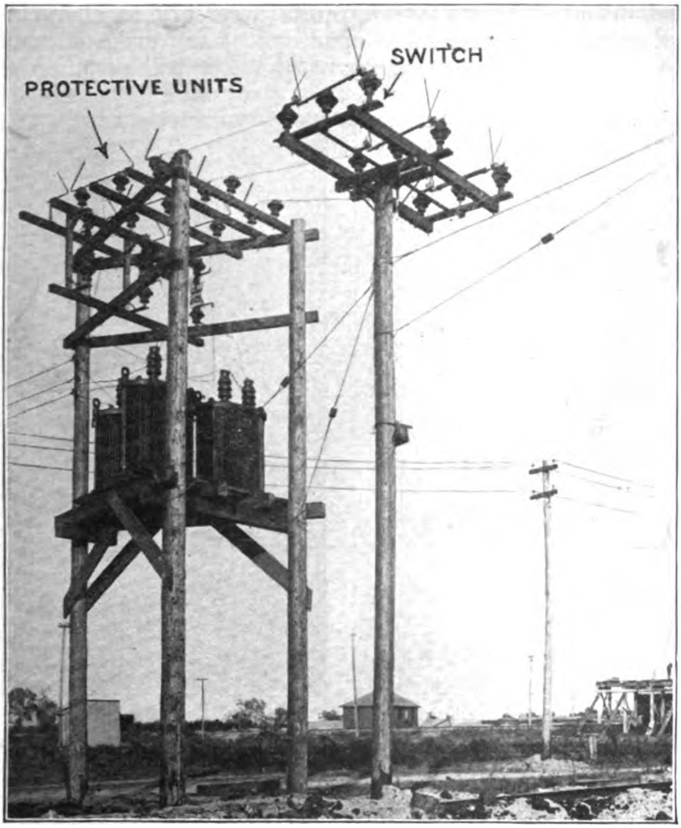


Fig. 12—33,000-Volt Station, Switch on Separate Pole

sub-station equipment branching from these lines will take care of itself so far as interruption to service is concerned, as any disturbance or trouble will be localized by the fuses and prevented from spreading to the main feeder lines—something of the highest importance.

OVERLOAD PROTECTION.

While automatic oil switches have been designed for outdoor service, it is questionable if they are suitable for use in connection with small sub-stations, as it is quite necessary to frequently inspect the contacts, height, and condition of oil, make adjustments, etc. A comparatively small amount of water will result in serious trouble, and inspection must be made in fair weather or with the switch under cover. Again the oil switch cannot be thoroughly inspected without killing the line, and when means are provided for by-passing the switch to cut it out of service, the necessary extra equipment becomes cumbersome and expensive.

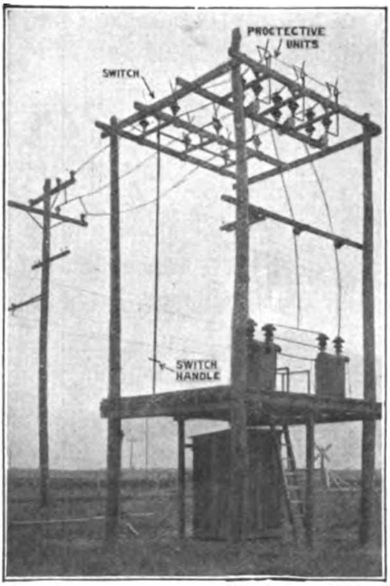


Fig. 13—33,000-Volt Station, Self-Contained Type

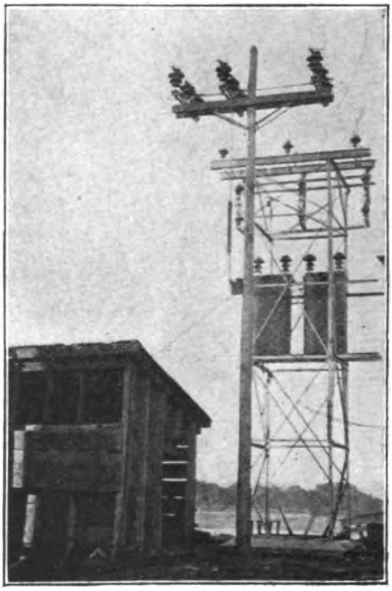


Fig. 14—33,000-Volt Steel Tower Outdoor Substation

The outdoor types of non-automatic air break switches with fuses have met the requirements of commercial service and are certainly far safer to install, inspect, and operate than are oil switches. Attempts have been made to employ the standard types of high tension indoor oil switches for outdoor service by providing housings, but this practically doubles the expense and still has the disadvantage of permitting no immediate and easy inspection when alive.

ADEQUATE FUSE PROTECTION.

The selection of a proper fuse to give adequate protection has been a vexing question, as the fuse must be of such design that it will not open under normal conditions, but will take care of those emergencies and abnormal conditions frequently arising in high tension distribution. One of the most successful types developed is the chemical form, consisting of a short fuse wire under tension and hermetically sealed in a glass tube filled with a carbon-tetrachloride solution. This form of fuse has the desired characteristics of quick action, minimum disturbance to the system, positive indication whether open or closed, and ready replacement.

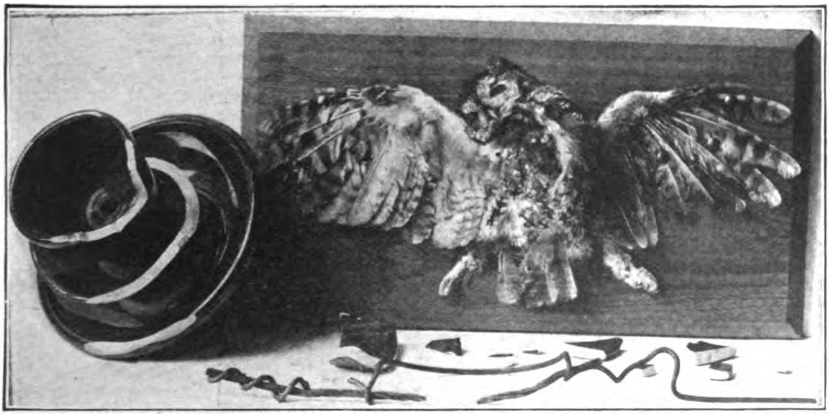


Fig. 15—Screech Owl After Striking 33,000-Volt Line

Aside from exhaustive laboratory tests, this fuse has been in successful commercial operation a sufficient length of time to thoroughly demonstrate its characteristics. Many short circuits have occurred on high capacity systems, and in every instance the fuse has cleared the lines without danger to either the feeders or generating installations.

An interesting illustration of fuse operation is shown in Fig. 16. This fuse, rated at 5 amp. 66,000 volts, was connected between one phase and the neutral point of a 110,000 volt bus fed by two 9,000 kv.-a generators operating in parallel. It will be seen that with the connections used, the fuses were subjected to approximately 66,000 volts, whereas on the regular 66,000 volt circuits, two fuses would always be in series in case of short circuit between phases. Should a short circuit occur between one phase and ground, the voltage across any fuse would approximate 38,000 volts, which is the usual method of operation. The successful performance under the conditions cited is conclusive evidence that the high tension fuses employed with the outdoor sub-stations illustrated are practical.

In Fig. 17 is shown an oscillogram record of a short circuit under exceptionally severe conditions as it was made soon after the pressure had passed zero and was rising. Figure 18 shows practically the same conditions. In both cases the fuse requires but one-half cycle to clear the lines.

EFFECT OF SLEET AND ICE.

The question is frequently raised as to the possibility of ice formation preventing operation of air break switches. To secure data on this point the following tests were made and the report was as follows:

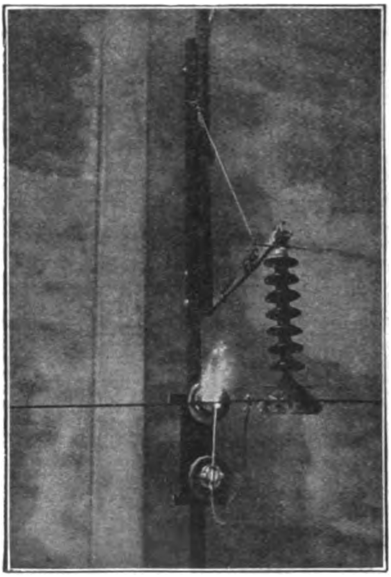


Fig. 16—66,000-Volt Fuse Blowing

A three pole, 33,000 volt switch was mounted on a temporary structure as shown in Fig. 19. The temperature was 25 deg. above zero, and the wind velocity was 25 miles per hour (as recorded by the Weather Bureau), a spray of water being directed on the switch for about 2½ hours. The ice deposit was very heavy and resulted in long icicles extending from the insulator petticoats to the channel-iron mounting, as shown in Fig. 20. Under the conditions illustrated, the flash-over occurred at potentials from approximately 51,000 volts to 57,000 volts; the values varied as the voltage was raised, and the icicles began to melt and stream. The spray of water which was kept playing on the switch kept the ice wet so that the combination of ice formation, thawing icicles, and steady water drizzle was probably equal to the worst conditions. That air break pole top switches as shown in Figs. 21 and 22 will operate under these conditions, is a good indication that they can be considered reliable for outdoor sub-station service.

In this paper only a few of the different types of stations in commercial service have been shown, but many others are in daily operation under widely varying climatic conditions. In general, the requirements of equipment are that the transformers be absolutely weatherproof, preventing entrance of moisture, and that the switching and protective gear be simple in design, effective, easily installed and have a low maintenance cost. The general tendency today is to use an air break switch capable of opening loaded circuits, a suitable fuse, discharging horn gaps, and a choke coil or inductance so located as to reflect excess potentials to the gaps where they can be discharged.

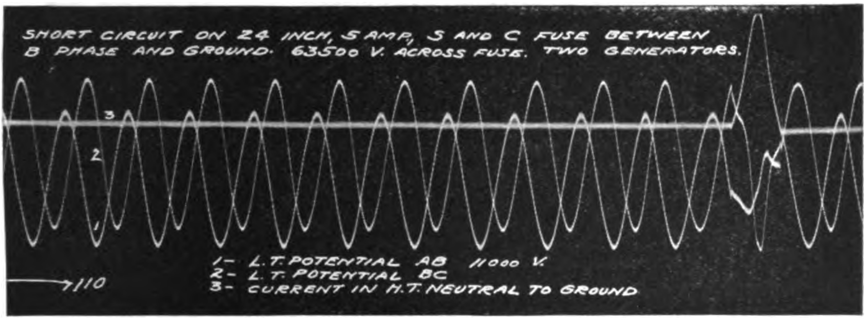


Fig. 17—Oscillogram Record of 66,000-Volt Short Circuit Test

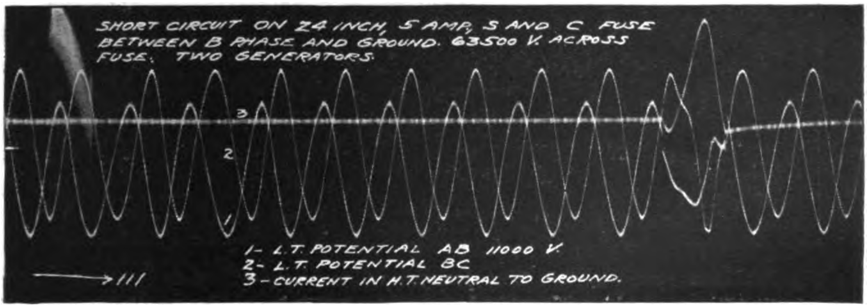


Fig. 18—Oscillogram Record of Second 66,000-Volt Test

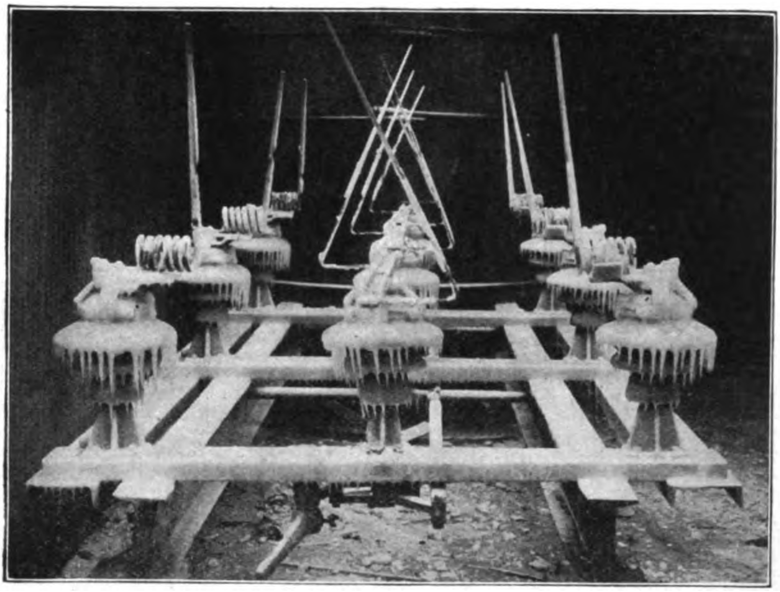


Fig. 19.—Ice Test on Pole Top Switch (End View—Open Position)

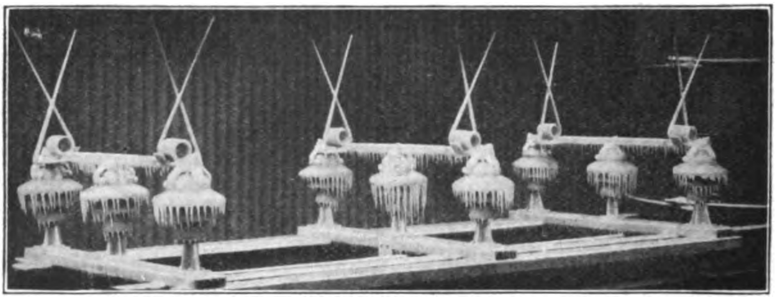
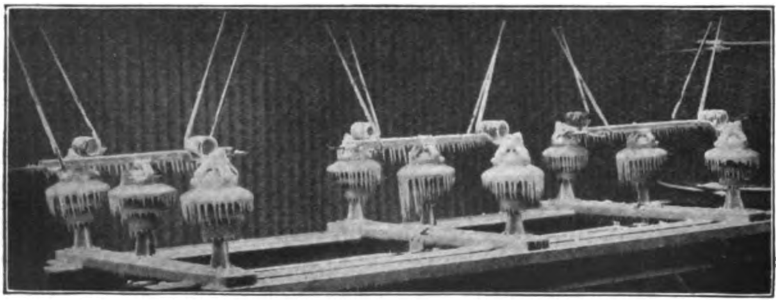


Fig. 20—Ice Test on Pole Top Switch (Side View—Closed Position)



Same as Fig. 20. Switch After Opening.

In closing, it can safely be predicted that the next two years will witness even a greater development in the design and use of outdoor sub-stations than has taken place in the past two years, so that central station managers will be in a position to take on a large class of rural consumers heretofore regarded as undesirable.

The illustrations accompanying this paper have been furnished by various central station and consulting engineers who have followed high tension development, and the writer desires to take this opportunity of extending especial thanks to the following:

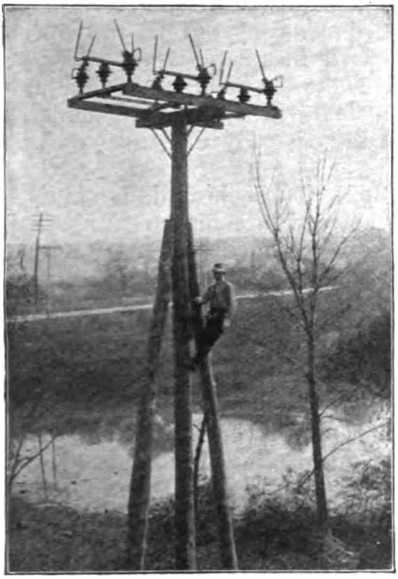


Fig. 21—Modern 33,000-Volt Pole Top Switch (Open Position)

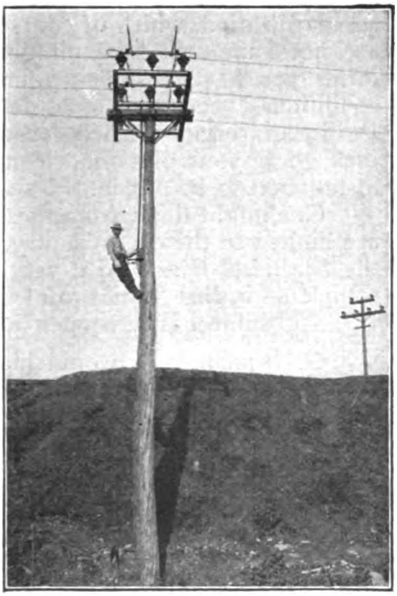


Fig. 22—Three Pole 33,000-Volt Switch (Closed Position)

J. C. Gapen, A. Herz, A. Alsaker, and C. W. Seibel, Public Service Co. of Northern Ill.

O. Wingard, Illinois Northern Utilities Co.
J. O. Hardin, Georgia Railway & Light Co.
E. S. Hight, Illinois Traction System.
M. J. Musser, Central Ill. Public Service Co.
N. M. Argabrite & C. G. Smith, Indiana Gen. Service Co.
Chas. Hahn, Northern Ill. Light & Traction Co.
H. C. Sterling, Constantine Hydraulic Co.
Sargent and Lundy, Chicago.
H. M. Byllesby & Co., Chicago.
Stone & Webster, Keokuk, Iowa.

DISCUSSION.

R. F. Schuchardt, M. W. S. E. (Chairman): These installations that Mr. Young has told us about are very interesting, indeed, especially when we remember that they represent a development dating back only a year or so. Some years ago almost any big transformer on a little platform with outdoor switches out in the country was called an outdoor sub-station. We find from the pictures shown us tonight that the modern outdoor sub-station in many cases requires as much real designing talent as many of the indoor type in the larger cities. A particular feature that appeals to anyone who has to do with sub-station installations, is the ease of standardization, which of course also helps to reduce the cost. You are not hampered by limitations of dimensions out in the open. After you have designed your standard installations for various conditions, you need only determine the capacity required and quality of service needed for any business in a new location and then go to your files for a complete set of ready drawings of the installation to be put in.

One might think from these pictures that such outdoor stations are limited to the open country, but we read in a recent number of the *Electrical World* of a very interesting outdoor sub-station just completed in that "Chicago of the South," Atlanta, Georgia.

The subject is now open for general discussion.

O. Wingard: I would like to know if anybody has had experience with the use of resistance connected between the horn gaps and ground of sub-stations.

Mr. Young: Last summer, while I was in Iowa, the question came up of interrupted service due to the discharge at the horn gap. In this particular installation the horn gap was located ahead of the fuse, so that any disturbance caused by current flow to ground would spread to the main system. I suggested that some form of a resistance in the ground circuit was necessary with that type of equipment, and found that Mr. Dravelle, the engineer in charge of operation, had designed a special type of water resistance. This resistance consisted of two ordinary jars or crocks holding about ten gallons of water each, in which were placed two electrodes, this being a single phase installation. With this form of resistance the horns have been set a little closer than usual and have frequently discharged; but in place of a vivid yellowish flame, characteristic of the earlier discharges, the flame became more violet or bluish in color. So far as I know, there has been no communication of local disturbance back to the station since the installation of the water resistance in the ground circuit.

With water resistance of this type it is necessary to place oil on the top of the water to prevent evaporation. During the winter time it will be necessary to draw off the water and reset the gaps a little wider apart to take care of surges, but setting the gaps to the original spacing in the summer when the resistance is again put in service.

This is the only case I know of where this particular type of resistance has been used. In some cases I have used special moulded resistance sticks on a 27,000 volt 25 cycle line, but found that they have invariably blown to pieces. In Canada I saw some Siemens resistances consisting of wire mounted in suitable form and immersed in oil; the tanks looked quite similar to those used for transformers. It is claimed that these resistances have limited the flow of current to ground, and while quite successful they are very expensive.

E. W. Allen, M. W. S. E.: I have had no experience with outdoor sub-stations, but would ask Mr. Young what setting he selected for his horn gaps. For example, on a delta system of 11,000 volts, between phases approximately what spacing is selected at 19,100 volts or twice the delta voltage?

Mr. Young: Our experience so far has been with the closed delta system. It is the practice in outdoor sub-stations to set the gap at approximately twice the insulation strength of the transformers. For example, a transformer wound for 33,000 volts will certainly withstand 66,000 volts. In such a case set the gaps to discharge at approximately 55,000 volts. Such gap setting has been working very satisfactorily.

Mr. Allen: Upon a closed delta system, if one phase arced over, would the other two go over?

Mr. Young: Yes, as a rule they would.

L. L. Perry (with Sargent & Lundy): Mr. Young touched upon the freezing of the switches. It is as important that a sub-station be built which will not freeze up, as it is that a sub-station be built which will not burn down. We all know how fires are likely to start out in the country in the grass, in the brush, and in various other ways. If we build a steel structure we know it will not burn down, and the cost of a steel frame is not much greater, if any, than that of the wooden frame.

Another advantage of the steel frame is that it can be torn down and rebuilt with practically no loss to its value, while with a wooden structure the value after being rebuilt is materially impaired. This is an important point in connection with such sub-stations as are of a temporary character.

Another point which should be taken into account is the difficulty of transportation. Many of these small sub-stations are built ten or twelve miles from a railroad. In Illinois they may have to be built at points where the material must be transported over very poor roads, and in the early spring, when the mud is about four feet deep, the transportation is exceedingly difficult. Under such conditions we can appreciate that we do not want to get our weights too heavy, and that is a point that bears on the selection of single-phase transformers as compared with the three-phase type. Assume, for instance, that we have a sub-station 15 or 20 miles from a good repair man or, say, from our source of supplies, and a three-phase transformer that weighs, say, three tons, burns out. There will be considerable difficulty in the way of transportation to replace that transformer, and during the time this replacement is being made, probably all the lights and power in town are out of commission. Consequently, there are some advantages in using single-phase transformers because one burnout will perhaps only reduce the capacity to about one-third; and two burnouts may still leave a lighting transformer to supply lights pending the transportation of an emergency transformer over some of these Illinois roads.

Mr. Schuchardt: Mr. Perry would go us one better. Instead of going to the file and drawing out a blue print and sending the men to install the apparatus, he would take the sub-station off the shelf, which would be quicker.

Wm. B. Jackson, M. W. S. E.: I am glad that Mr. Young consented to prepare and present this paper, for it is on an extremely timely topic and by a man well qualified to discuss it both on account of study and experience.

The outdoor sub-station has already become an important factor in our electrical transmission and distribution systems, and it seems to me that only a mere beginning has yet been made in the line of its possible development. It is difficult to say what is likely to be the ultimate development of such sub-stations, but it is probably safe to predict that the development will, as in the past, be along lines of more or less gradual evolution, and where such is the condition the development is likely to be large and sure.

I will relate an interesting prophecy regarding outdoor sub-stations which occurred about eleven years ago. I was inspecting the transmission lines of the Bay Counties Electric Company, accompanied by one of the company's engineers, and we arrived at a sizable temporary sub-station, the equipment of which was enclosed only by the corner posts and roof stringers of the sheet iron building that was to cover it. This was entirely feasible, as it was then the dry season. When we reached this sub-station my companion remarked that, in his opinion it would not be many years before substantially all of their sub-stations would be constructed for regular operation out in the open. This was not so long a flight of the imagination for one living on the Pacific Coast as it would have been for one living in our eastern cities, but eleven years ago it was a pretty good flight even there.

H. B. Gear, M. W. S. E.: Mr. Jackson has described my position exactly. It is more or less that of one who sits and watches the procession go by rather than one who mixes with the crowd. I believe that the work which is being done in connection with the development of outdoor sub-stations is of very great value to the development of the industry as a whole. The ability to make aggregations of small central stations into one large system is very largely made possible through the development of this outdoor apparatus. The towns which are picked up on these lines are almost all less than 100 kw., a great many of them less than 50 kw., and as a pioneering proposition an outdoor installation is practically the only sort which is a commercial possibility. These transmission lines, such as those of the Illinois Northern Utilities Co. and the Public Service Co., which stretch out over 50 or 60 miles at 33,000 volts and pick up a town here and a town there, would have been impossible ten or twelve years ago, because the apparatus with which to connect up these towns and take them on was not available. The expense of buildings and apparatus would make it commercially impossible to give service in many of the towns through which these lines go.

The development of outdoor types of switches to handle these things, together with choke coils, air gaps, etc., and the development of types of outdoor fuses which will take care of considerable amounts of load at high voltages, are two of the most important factors in the development of this art. Of course, the equipment of transformers with outdoor terminals and the development more recently of outdoor types of regulators for street lighting and for other service have contributed their share.

Looking ahead, the field for the outdoor automatic regulator is a large one. In many of these places it would be impossible for good commercial regulation to be given for lighting service, and as the load conditions will vary from hour to hour during the day on the main transmission line where there are large units of power, like coal mines and other large industrial service, it will be necessary to have larger sizes and larger installations of potential regulators automatically operated in the open. There are some places in the outlying parts of Chicago where these automatic regulators would contribute toward a better service, because some of the distribution is of a suburban character even within the city limits.

I think that the paper of the evening marks a distinct line of progress in the development of distribution engineering.

James R. Cravath, M. W. S. E.: Last year I had occasion to put up a small sub-station which was intended originally to be all indoors. Before I got very far I concluded that I could reduce the fire risk and also the cost by putting the transformers outdoors, and the switchboard and regulating apparatus indoors. That was before the development of any outdoor regulators. The result was satisfactory.

L. N. Boisen (with Central Illinois Utilities Co.): In a town having 300 inhabitants we get a revenue from street lighting of $900.00 per year, and there are fifty customers and two grain elevators connected on two 25 kw. transformers outdoors. If we had been obliged to put in indoor sub-stations, we would probably not have taken that town as a customer.

I think that one very important question in connection with the outdoor sub-station is the fuse protection, and Mr. Young seems to be absolutely in favor of placing fuses between the discharge to the ground and the line. We have had instances where, during a severe lightning storm, as high as ten shut-downs occurred from blown fuses, whereas in other sub-stations where the fuses had been placed between the line and the transformer only, leaving the ground arc unprotected, we had momentary interruptions of service, due to lowering voltage. The voltage being cut down considerably, it would of course throw a rather heavy momentary load on the station. It seems to me that the choking effect of the line, and possibly the choking effect of the ground wire used in connection with it, limited to some extent the power discharged in the arc. We had no serious trouble at the station proper.

The interruption of service is something in which all central station operators are interested. Placing the fuse on the transformer side—on the line side of the discharge to ground—might in some cases mean a great number of interruptions from one lightning storm. I think some method will be developed whereby a system of resistances can be placed in the ground connection. We are doing some experimenting with various forms of resistances—for instance, in the form of concrete blocks—and I believe that some satisfactory development can be made along these lines.

F. C. Van Etten: Mr. Gear, in speaking of regulating apparatus in connection with outdoor sub-stations, no doubt refers to the future. For the present, at least, the primary object in the design for such stations is to reduce the cost to a minimum, using only that equipment which is absolutely necessary, which will give satisfactory operation, and which can be obtained and erected at the very lowest cost. Steel towers have been seldom used simply because wooden structures are cheaper. In new installations the return on the investment is often very small, sometimes there is a loss, but it occurs to me that this loss could be charged, theoretically at least, as an advertising account, for an existing line and station is one of the best advertisements to attract the farmers and people in small towns. As the load on the line increases, more elaborate equipment, including steel towers, regulating apparatus, etc., can be used, and the original equipment can be transferred to another point.

As a specific instance showing that the cost of the equipment installed must be reduced as much as possible, I will call your attention to the mounting of the switches as shown this evening. The single pole mounting of the switch has become very popular and is much preferred to the double pole arrangement, simply because the latter requires the extra pole.

A remark of the Chairman might lead one to believe that there is all out of doors for the installation of sub-stations. Looking about the country, we see nothing but the blue sky above us and the fields about us and we ordinarily think that there is a large area upon which we can spread a sub-station, but there are times when the space in which a sub-station may be erected is exceedingly limited. I recall a plat lying between two railroad right-of-ways which converged at an angle of about 30 degrees, the base of this triangular piece of ground being about 15 ft. long. Upon this plat it was necessary to install a station with a capacity of three 100 kw. and three 75 kw. transformers, as well as provide for a 33,000 volt incoming line and two outgoing lines—one 6,600 volt line in one direction and one 2,200 volt line in the opposite direction. In other instances where transmission lines are built just inside of railroad right-of-ways, the poles for the sub-station must be placed in a line and the complete installation arranged so that it does not project over the farmer's land.

Dr. M. G. Lloyd: One question occurred to me while I was looking at the lantern slide views, which I should like to bring up. It refers to the view of the case where the fuse was connected between the gap of the horn gap and the ground. These fuses have a structure in the form of a spiral spring or coil inside a glass tube, and I was wondering whether the impedance of the fuse itself in that position might be objectionable. I understand there has not been much experience with that particular construction. It occurred to me that the impedance in that line might tend to prevent somewhat the reduction quickly of a high potential by the gap. I do not know just what the value of that impedance is. The number of turns is comparable, probably, to the ordinary choke coil. The area of the turns being very small would keep the impedance down, but at such frequencies as we have in the lightning discharge I should think that the impedance might possibly be of some importance and make it undesirable on that account to have the fuses on that side of the gap.

Mr. Young: I should have described the fuse. The coil is shunted by a flexible wire or cable so the condition cited would not occur.

Mr. Wingard: Would it be advisable to have a fuse placed on the station side of the choke coils instead of on the line side?

Mr. Young: That is a point about which I know very little. Sometime ago at an installation where Mr. Wingard had the fuse on the line side of the choke coil I suggested that it be placed on the transformer side. He asked me why, and I told him for the reason that last year on one system where fuses were installed ahead of the choke coils, there seemed to be more trouble due to blowing than when the fuses were behind the coil.

D. W. Roper, M. W. S. E.: I would like to inquire if sleet collects on the switches to such an extent as to interfere with their operation. Suppose you want to open or close a switch or do something with it; would the ice bother you in the operation of the switch?

Mr. Young: That is a point which I wish especially to make clear, as it is found that in spite of ice and icicles the switches will open. This action is due simply to the shearing and bending action of the flat underwipe contacts. The same action can be observed with any flat surface coated with ice. By giving it a little rap with a hammer or a stick the sleet will rattle off. The same action occurs at the auxiliary contacts or arcing hours. When moved they bend, and the ice rattles off, and as the underwipe contacts go into position they strike the icicles at the base and shear them off. The main contacts are also flexible, being made of flat phosphor bronze spring. A good way to demonstrate the action of this type of contact is to take a piece of phosphor bronze and form ice on it. Then on bending it you will find the ice rattles off. That is the way the switch operates, and you can close and open it under severe ice conditions.

Mr. Schuchardt: I think we all appreciate the importance of the subject, and also the opportunity we have had tonight of learning the present status of this subject.

IN MEMORIAM.

JAMES WHITING JOHNSON, M. W. S. E.,

Died January 14, 1913.

James Whiting Johnson, Manager of the Chicago District of the General Electric Company, died of pneumonia, at his home in Hyde Park, Chicago, on Tuesday, January 14, 1913, after a short illness.

Mr. Johnson was born in Waverly, N. Y., December 3, 1862, and was the son of the Rev. David S. Johnson, for many years Pastor of the Hyde Park Presbyterian Church. Since his boyhood Mr. Johnson has lived in Chicago and was a student at the Hyde Park High School. In 1878 he began his business career in the employ of the Bell Telephone Company, and remained with that company and its successor, the Chicago Telephone Company, until 1885. For two years thereafter he was managing partner of the firm of Johnson, Holland & Company, which was formed to exploit the storage battery business. In 1887 Mr. Johnson became Manager of the Northwestern Electric Accumulator Company; and a year later he entered the Chicago Office of the Thomson-Houston Electric Company as a salesman. With this company and its successor, the General Electric Company, he was connected until the time of his death, with the exception of a period of about three years, when he was Western Agent for the United States Fire & Police Telegraph Company of Boston.

In the early days he was Manager of the Isolated Plant Department of the Thomson-Houston company, and later was successively Chicago Manager of the Lighting Department and of the Power & Mining Department of the General Electric Company. In 1905 he was made Assistant Manager of the Chicago Office, and since May, 1908, when Mr. B. E. Sunny resigned to become President of the Chicago Telephone Company, he had been District Manager.

Mr. Johnson was a dignified, quiet man of great business intelligence, a painstaking, untiring worker, and appreciative employer, a faithful friend and a highly respected and just executive, whose loss will be most keenly felt by his friends and associates in the business world.

He was a member of the Union League, the Chicago Automobile, the Mid Day and the Homewood Country clubs in Chicago, and of the Mohawk Club in Schenectady, N. Y. He was also a member of the Western Society of Engineers and of the American Institute of Electrical Engineers.

Memoir prepared by E. W. Allen and P. Junkersfeld, Committee.

February, 1914

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Regular Meeting, February 2, 1914.

A regular meeting of the Society (No. 849) was held February 2, 1914. The meeting was called to order at 8:10 p. m., by President Lee, with about 130 members and guests in attendance. The Secretary reported from the Board of Direction, that applications for admittance to the Society or for transfer had been received from the following:

Harold P. Weaver, Chicago, transfer.
Earle C. Hazlett, Los Angeles, California.
Barnabas Schreiner, Oskaloosa, Iowa, transfer.
Elmer Lawrence Andrews, Montpelier, Indiana.
Royal Heber Drummond, Fargo, North Dakota.
William O. Lichtner, Newton Highlands, Mass.
Herbert Edson Hudson, Chicago.
Isaac Van Trump, Chicago.
William Hiram Fursman, Henryetta, Oklahoma.
Henry Ericsson, Chicago.
Arnold N. Lurie, Chicago, transfer.
Frederick T. Snyder, Chicago.
Henry J. Kaufman, Chicago.

There being no other business, Mr. E. J. Mehren, editor of the *Engineering Record,* New York, was introduced, who addressed the meeting on "The Making of a Technical Paper." This was illustrated with some lantern slides and some copper and zinc engravings, such as are used in printing a paper.

A social time followed the presentation of the paper.

Meeting adjourned about 10:30 p. m.

Extra Meeting, February 9, 1914.

An extra meeting of the Society (No. 850), a meeting of the Bridge and Structural Section, was held Monday evening, February 9, 1914. The meeting was called to order at 8:05 p. m., by Mr. J. H. Prior, chairman of the section, with about 100 members and guests in attendance. Mr. Ernest McCullough was introduced, who presented his paper, which had been printed in advance, on reinforced concrete columns. Discussion of the subject followed in which Messrs. F. E. Davidson, T. L. Condron, J. H. Prior, W. E. Ramsey, W. A. Hoyt, H. S. Shimizu, J. L. McConnell, F. H. Wright and F. G. Vent, took part. Mr. Condron read his discussion of the subject, and Mr. McCullough read a contribution from Mr. Godfrey of Pittsburgh.

The meeting adjourned at 10:15 p. m.

Extra Meeting, February 16, 1914.

An extra meeting of the Society (No. 851) was held Monday evening, February 16, 1914. The meeting was called to order about 8:15 p. m., when the President introduced Dr. Patrick S. O'Donnell, who addressed the meeting on Radium. There was an exhibition of $25,000 worth of bromide of radium, and sundry optical and physical experiments were made in illustration of the subject. Also a number of stereopticon views were shown.

Dr. J. Rawson Pennington followed with further remarks on the subject. Meeting adjourned about 9:45 p. m. There were over 200 in attendance at this meeting.

Extra Meeting, February 23, 1914.

An extra meeting of the Society (No. 852), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Monday evening, February 23, 1914. The meeting was called to order at 8:25 p. m. by the chairman, D. W. Roper, with about 50 members and guests in attendance. The chairman introduced Mr. Hill of the G. E. Co., who presented, with lantern slide illustrations, a description of "The Switch Boards for the Control of the Panama Locks." Afterwards a motion picture showed the operation of the switch board. Some questions were asked of details of construction by Messrs. H. E. Goldberg, Geo. M. Mayer and J. F. Hayford. A vote of thanks was returned Mr. Hill for his address.

Meeting adjourned at 9:55 p. m.

BOOK REVIEWS

The Books Reviewed Are in the Library of This Society.

PRACTICAL ALTERNATING CURRENTS AND ALTERNATING CURRENT TESTING. By Charles F. Smith, M. Sc., M. I. E. E.; Assoc. M. Inst. C. E.; Whit. Schol. The Scientific Publishing Co., Manchester, England. Cloth, 5½x8½ in.; pp. 398. Price, 6s, net.

The book treats the various subjects from an experimental standpoint and takes in all the theory necessary to make the subjects easily comprehended. The excellent style which the author uses in treating the subjects by employing simple and clear words and well-chosen methods accompanied by Vector diagrams and curves obtained from actual tests of the apparatus treated, assist the reader materially in understanding the subjects thoroughly and convey concrete ideas of the principles of alternating currents and characteristics of alternating current machinery. The thorough and detail explanations used make the book a valuable one to the student desiring knowledge along the subjects covered therein and also valuable to the practical engineer as a reference book.

In conclusion, the reviewer wishes to call attention to the term "apparent ohms" used frequently by the author. Since impedance affects alternating current in a manner similar to that of resistance in direct currents, impedance may be correctly called "apparent resistance." However, as impedance is actually measured in ohms, the same as resistance, correctness of the term "apparent ohms" in referring to impedance appears, therefore, somewhat questionable.

The third edition of this book was reviewed in the June, 1910, issue of our journal, page 427. C. J. H.

SUSPENSION BRIDGES AND CANTILEVERS, THEIR ECONOMIC PROPORTIONS AND LIMITING SPANS. By D. B. Steinman, C. E., Ph. D., Professor of Civil Engineering, University of Idaho. D. Van Nostrand Co., New York. 1913. Boards: 3½x6 in.; pp. 185. Price, 50c.

This little book is presented in the nature of an investigation by the author, of the economic proportions and limiting lengths of span for the longer types of bridges with which the bridge engineer may come into contact, the revised edition drawing sharp distinction between the theoretic and practical limits.

The author presents, in a clear and concise manner, much valuable data, such as formulas for weights, cost, etc., together with notable examples of existing structures.

His theoretic and practical discussion of the best economic selection of the type of bridge best suited for the place supplies a longfelt want.

F. G. V.

AMERICAN RAILROAD ECONOMICS. A text-book for investors and students. By A. M. Sakolski, Ph. D., New York. The Macmillan Co. 1913. Cloth; 5x7½ in.; 295 pp., including index. Price, $1.25.

"This book is the product of the author's activities as an investment analyst in New York, and as an instructor in Railroad Finance at the New York University School of Commerce, Accounts and Finance."

It is an interesting and valuable book, which analyzes the varied elements of railroad business, and draws comparisons which are necessary for correct judgment. The author does not present a multitude of statistics, which may be misleading, but submits various railroad data, as (1) those relating to the character of transportation facilities, as the physical features which influence operations; (2) measuring efficiency and economy of operations, as traffic and rentage statistics, expressed in proper terms and in standard units; (3) the measuring of revenues, expenses and net earnings; and (4) data measuring the capital investment in relation to corporate resources and liabilities.

The first chapter takes up the subject of Railroad Rates, the theory of regulation, the factors of within and without a state, the effect of sectional competition, the long and short haul, etc.

In the next chapter the author takes up the subject of railroad securities, capital stock, preferred and common stock, funded indebtedness, mortgage bonds, trust bonds, income bonds, and short term securities. The difference between these several classes is shown, their value and their limitations.

The Railroad Systems of the United States is the subject of Chapter III, describing the development of the systems and their geographical location, as the New England systems, the Trunk Line systems, the Southern systems, the Northwestern and the Southwestern systems, and others. Traffic interchange agreements are also considered in this chapter.

In Chapter IV consideration is given to economics of railroad construction. This relates to investment basis of railroad construction, the nature of the prospectus, issued to secure stock subscriptions, or other funds from the general public, and must include a statement of probable volume of traffic which is to bring in returns on the investment, and it is also dependent on the rates to be charged. In addition comes the selection of the route, the construction cost and the fundamental economic principle of modern railroad construction.

The Physical Factors in economic operations, way and structure, is the subject of the next chapter. This includes location with grades and curves, roadbed and superstructure, ties, rails, and ballast, also bridges and trestles, tunnels and terminals.

The next chapter gives consideration to rolling stock equipment, as locomotives and cars.

Traffic Statistics is the subject of Chapter VII; both passenger and freight traffic are considered, with classification of statistics, the unit of measurement of operating economy, as the train mile, the car mile, etc.

The Interstate Commerce Commission has formulated a system of railroad accounts, and these are set forth in Chapter VIII.

The Income Account and Operating Accounts, the Net Income and Its Distribution, and the General Balance Sheet, are the topics of Chapters IX, X and XI, while the final chapter, XII, treats of Railroad Capitalization.

The book, as would be expected from its source, is more concerned with the financial features of railway business than the more physical view of design, construction and operation, but none the less it is a valuable book for an engineer to read and consider.

POWER PLANT TESTING. A manual of testing engines, turbines, boilers, pumps, refrigerating machinery, fans, fuels, lubricants, materials of construction, etc. J. A. Moyer. McGraw-Hill Book Co., New York. 1913. Clothbound; 6x9 in.; 486 pp., including index, many illustrations, tables, etc. Price, $4.00.

The first edition of this work is dated Ann Arbor, Mich., August, 1911, and was intended to give in a moderate volume, but somewhat in detail, the generally approved methods of testing engines, turbines, boilers, and the auxiliary machinery, usual to power plants. In addition to this it was found desirable to add chapters on the testing of fuels, hydraulic and refrigerating machinery, and other tests on the strength of materials commonly used in building construction. As the book was intended particularly for class use at the beginning of laboratory periods, and with a number of different experiments and tests, care was taken to state clearly the apparatus to be used, and the precautions to be observed to secure accuracy of results. But above all it was desired that students should learn to rely mostly on their own initiative. A good deal of the training necessary to secure accurate and reliable work in the observing and interpreting results, by the operator of tests of machinery, is to be familiar with adjustment and calibration of instruments, and this has been developed so they may be used intelligently. The present volume, somewhat enlarged, has been amplified, including the addition of the latest revisions of the standard code of 1912 adopted by the Power Test Committee of the American Society of Mechanical Engineers, and also in other particulars, to make the book more acceptable to the numerous engineering schools, now using this work as a text book. The broad scope and comprehensiveness of the first edition, though at the expense of completeness as a manual, made the first edition attractive to teachers, but this second edition has increased the comprehensiveness and without adding too much detail bewildering to the student. To those interested in such research work the book is to be commended.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

NEW BOOKS.

D. Van Nostrand Co.:
- Engineering Valuation of Public Utilities and Factories, H. A. Foster. Cloth.
- The Absorption Refrigerating Machine, G. T. Voorhees. Cloth.
- Hydroelectric Development and Engineering, Frank Koester. Cloth.
- Güldner's Internal-Combustion Engines, H. Diederich. Cloth.

McGraw-Hill Book Co.:
- Economics of Interurban Railways, L. E. Fischer. Cloth.

MISCELLANEOUS GIFTS.

Boston Department of Public Works:
- Annual Report, 1912. Cloth.

Philadelphia Bureau of Surveys:
- Annual Report, 1912. Cloth.

Metropolitan Sewerage Commission:
- Preliminary Reports on Disposal of New York's Sewage, Vols. VIII, IX, X; 3 pams.

John L. Parsons, M. W. S. E.:
- Handy Tables for Computing Cost of Tile Drains. Pam.

Scientific Publishing Co.:
- Fowler's Mechanics' and Machinists' Pocket Book and Diary, 1914. Leather.
- Fowler's Mechanical Engineers' Pocket Book, 1914. Leather.

H. G. Tyrrell, M. W. S. E.:
- A Tube to Ireland. Pam.

Universal Portland Cement Co.:
- Monthly Bulletin, 1913. Leather.

New York City Board of Water Supply:
  Reports, Letters, etc., on the City Tunnel. Cloth.
New York State Engineer:
  Annual Report, 1912. 2 vols., cloth.

EXCHANGES.

Master Car Builders' Association:
  Proceedings, 1913, Parts I and II. 2 vols.; cloth.
American Society of Heating and Ventilating Engineers:
  Transactions, 1912. Cloth.
University of Missouri Engineering Experiment Station:
  Artesian Water in Missouri. Pam.
University of Illinois Engineering Experiment Station:
  Coal Washing in Illinois. Pam.
Lake Superior Mining Institute:
  Proceedings, 18th Annual Meeting, 1913. Paper.
Illinois State Geological Survey:
  Petroleum in Illinois in 1912 and 1913. Circular.
Illinois State Mining Board:
  Thirty-second Annual Coal Report, 1913. Cloth.
Canada Commission of Conservation:
  The Canadian Oyster. Cloth.
Junior Institution of Engineers:
  Transactions, Vol. 23, 1912-13. Cloth.
Virginia Geological Survey:
  Geology of the Titanium and Apatite Deposits of Virginia. Cloth.

GOVERNMENT PUBLICATIONS.

U. S. Bureau of Mines:
  Bulletin No. 66, Tests of Permissible Explosives. Pam.
  Technical Paper No. 50, Metallurgical Coke. Pam.
  Technical Paper No. 54, Errors in Gas Analysis Due to Assuming That the Molecular Volume of All Gases Are Alike. Pam.
  Technical Paper No. 56, Notes on the Prevention of Dust and Gas Explosions in Coal Mines. Pam.
  Monthly Statement of Coal Mine Fatalities, November, 1913. Pam.

U. S. Geological Survey:
  Bulletins Nos. 531, 536, 538, 539, 542, 545, 555. Pams.
  Water Supply Papers Nos. 295, 302, 303, 319, 320, 333, 334, 337. Pams.
  Professional Papers Nos. 76, 85b, 85c. Paper; quartos.
  Geological Folios Nos. 185, 187, 188, 189, 190.
  Thirty-fourth Annual Report for year ending June 30, 1913. Pam.

U. S. Coast and Geodetic Survey:
  Triangulation of the Coast of Texas from Sabine Pass to Corpus Christi Bay.
  Annual Report of Superintendent for Year ending June 30, 1913. Cloth.

Bureau of the Census:
  Mortality Statistics, 1911. Cloth.

U. S. Department of Agriculture:
  The Floods of 1913 in the Rivers of the Ohio and Lower Mississippi Valleys. Paper.

VOL. XIX, No. 3. MARCH, 1914

JOURNAL

OF THE

WESTERN SOCIETY

OF

ENGINEERS

CONTENTS

The Necessity of Ventilation. Meyer J. Sturm 233

Discussion:

By F. E. Davidson, J. W. Shepherd, H. J. Thorkelson, Wm. B. Jackson, Albert Scheible, E. N. Layfield, H. Gansslen, W. W. DeBerard, F. J. Postel, J. R. Cravath, Ernest McCullough, Mr. Sturm.

A Campaign to Prevent Fire. Franklin H. Wentworth 258

Discussion:

By F. E. Davidson, J. C. McDonnell, E. W. Case and W. C. Robinson.

The Cement Gun and Its Work. Carl Weber 273

Discussion:

By J. H. Prior, R. S. Draper, E. B. Wilson, C. W. Boynton, C. W. Melcher, D. P. Gaillard, O. F. Dalstrom, H. S. Baker, J. H. Libberton, William Seafert and Mr. Weber.

Memorials—

Charles Edward DeCrow 316

Adam Comstock 317

Proceedings of the Society, Minutes of Meetings 319

Book Reviews 320

Library Notes 322

Membership 324

Index to Advertisers XXII

CHICAGO

Published Monthly, Excepting July and August, by the Society,
1735 Monadnock Block.

Entered as Second-Class Matter March 9, 1896, at the Postoffice at Chicago, Ill., under Act of March 3, 1879.

Subscription Price, $3.00 per Volume of Ten Numbers.

50 Cents a Single Number.

Copyright, 1914, by the Western Society of Engineers.

WESTERN SOCIETY OF ENGINEERS

1735 Monadnock Block, Chicago, Illinois.
Phone Harrison 945.

OFFICERS FOR 1914.

President...E. H. Lee, Dearborn Station
First Vice-President.........................B. E. Grant, Room 307 City Hall
Second Vice-President.........Ernest McCullough, 1302 Monadnock Block
Third Vice-President..........................F. Gerhardt, Armour Institute
Treasurer...........................C. R. Dart, Room 700, 900 Michigan Ave.
Trustee.........................J. G. Giaver, 1 year, 1417 Railway Exchange
Trustee.......................F. E. Davidson, 2 years, 1448 Monadnock Block
Trustee....................................H. S. Baker, 3 years, 402 City Hall

Past Presidents on the Board of Direction.

O. P. Chamberlain.........................108 So. La Salle St.
W. C. Armstrong.........................226 W. Jackson Blvd.
Albert Reichmann.........................72 W. Adams St.

ELECTRICAL SECTION

Executive Committee

F. J. Postel, Chairman; H. M. Wheeler, Vice-Chairman
G. T. Seely..1 year
P. B. Woodworth..................................2 years
E. W. Allen..3 years

BRIDGE AND STRUCTURAL SECTION

Executive Committee

J. H. Prior..Chairman
J. W. Musham................................Vice-Chairman
E. N. Layfield H. C. Lothholz I. F. Stern

HYDRAULIC, SANITARY AND MUNICIPAL SECTION

Executive Committee

W. D. Gerber..Chairman
G. C. D. Lenth..................................Vice-Chairman
W. W. DeBerard Douglas Graham Langdon Pearse

Secretary............J. H. Warder

The Chanute Medals

The Board of Direction, W. S. E., desire to announce that the Octave Chanute Medals will be awarded for the most meritorious papers on Engineering subjects presented before this Society by members thereof during the year 1914.

Journal of the
Western Society of Engineers

VOL. XIX MARCH, 1914 No. 3

THE NECESSITY OF VENTILATION

By Meyer J. Sturm, M. W. S. E.

Presented December 15, 1913.

The object of this paper is to treat the entire subject of ventilation from the standpoint of the necessity of ventilation, rather than to present methods of ventilation. In order to do this I will give some statistics to show that fresh air is the most essential thing in life.

What is ventilation? Some years ago this question was put to me by the Health Commissioner, and I answered, "Ventilation is fresh air and plenty of it." The Commissioner then said, "Well, if that is ventilation, how are you going to get it?" My reply was, "Open the windows, top and bottom."

That was some years ago and I thought then that my replies had fully covered the whole ground. I have not changed my mind on the principle, but if that were all there is to ventilation, I would not be here this evening. Only last week the Chicago Commission on Ventilation, of which I am a member, discussed for three hours whether the open window contributed anything to mechanical ventilation—whether it did not retard such ventilation—and expressed some doubt as to the efficacy of changing the air by direct means when artificial means are employed.

Ventilation, up to the time of the convening of the ventilation commission, was based almost wholly on theoretical values. Some sporadic experiments had been made by individuals, but these were on specific lines, more or less along the physical, to demonstrate practically the physiological effect of impure air due to pollution from two sources,—the presence of CO_2 gas, and an unknown contributory factor. It is only recently that any concrete results have been obtained, due to the fact, in the first place, that there had been, up to the time of the work of the commission, an erroneous hypothesis upon which experiments were made; and in the second place, because, even in the light of the rapid strides forward, we are still at sea as to what really is the deleterious substance in vitiated air.

McFie, in his recently published work, Air and Health, says:

"Air containing merely the carbon dioxide and moisture

> usually contained in vitiated air will not produce the effect of vitiated air, and vitiated air, therefore, must contain an additional constituent. This additional constituent, though undetected by chemists, is probably detected by the nose, for it is well known that air is oppressive and harmful not so much in proportion to the amount of carbon dioxide and moisture it contains as in proportion to its smelliness. The very fact that the nose is so sensitive to such odors would seem to suggest their harmfulness."

Without doubt this unknown constituent which gives the obnoxious odor or smell to bad air, such as is evident in assemblies, most noticeable in warm rooms as in our nickel theaters, is a harmful factor.

Permit me to present to you, in order to bring this subject of ventilation before you properly, that the ventilation commission has adopted as its "Confession of Faith" over fifty resolutions pertaining to various phases of ventilation. All of these resolutions were adopted only after thorough experimentation, and none of them are theoretical. I cannot attempt to go into all of these, or too minutely into any of them, as each one is a theme for discussion. The commission has been in existence almost four years and has been constantly working on these resolutions or the experiments which led up to their adoption. I can give to you this evening only an outline of a few of those which will probably be of interest to you. Within a few weeks the entire findings of the commission will be in print and you will then have available the first comprehensive exploitation of this subject. The commission does not claim that this is the last word on ventilation problems, but merely a nucleus or a working basis for further research.

The ventilation commission is wholly voluntary in its character, and among its members are men connected with the health department. Dr. Young is chairman of the commission. Some of the other members are: Dr. Vernon Hill, head of the ventilating division of the Sanitary Bureau; Dr. Toney, of the municipal laboratory, and Dr. Evans. Due to the activities of these men, the commission has been able to make quite a number of experiments, making various tests in theaters and assembly halls. The second contributory cause to our success has been the coöperation of the Board of Education, which has kindly fitted up an experimental station at the Normal School, where we have the high school children, under the direction of Professor Shepherd, secretary of the commission, who is with us this evening.

The commission has been hampered greatly in its work, due to the fact that it has not had sufficient funds to set forth its findings as it should. Through the kindness of the associations which are now affiliated with it, namely, the Illinois Chapter of the American Society of Heating and Ventilating Engineers, the Chicago Architects' Business Association, and the Illinois Chapter of the

American Institute of Architects, we have been able to get a small fund besides that which has been contributed personally by members, and the findings will be distributed as well as they possibly can be under the conditions.

The first resolution passed by the commission was to the effect that CO_2 as encountered in ordinary expired air does not settle out from a mixture of air and CO_2. By numerous experiments this has been found to be true, and in consequence thereof the entire theory of ventilation has been disproved, inasmuch as all mechanical ventilation, up to the time that the commission gave out this finding, has been based upon the removal of the CO_2 from the lower stratum of air near the floor.

Now, as an architect and not as a ventilating engineer, I can vouch for the fact that up to a year or two years ago no attempt was made by architects or ventilating engineers to do anything but remove that supposed or theoretical stratum of CO_2 from the air near the floor in all ventilating systems. In other words, all air was brought in about 8 ft. from the floor and outlets were provided at the floor for taking off the vitiated air, on the theory that the CO_2 gas was at the floor level waiting to be taken out; the fresh air was brought in at the top to force it down and out.

As stated before, the CO_2 in itself is not a deleterious substance, but is an index of the air contamination in almost every instance. Therefore if the CO_2 does not settle out, as has been found in actual practice, and 10 parts in 10,000 is not deleterious, we have a working hypothesis which would indicate that the other deleterious substances in the expired air are the real menaces in the so-called bad air. The amount of CO^2 permissible in air can be readily calculated when it is understood that air as encountered in nature has four parts of carbon dioxide.

Dr. Vernon Hill, of the ventilation commission, proposes that a simple formula is one in which 6000 is divided by the cubic feet per hour of the air supplied, and to this 4 is added as the safe working limit for the amount of carbon dioxide permissible in the air in enclosed spaces. For example, if 1800 cubic feet of air per hour per capita was being supplied to a room, there would be approximately 7½ parts of carbon dioxide present, which would be below the maximum allowed as safe practice.

I call your attention to the experiments of Leonard Hill made in London within the last year, in which he found that there was an appreciable difference under the same conditions when air was without motion and when in motion. To arrive at a conclusion, he built an air-tight room with glass sides so that he could more readily observe the subjects and in this room he put men. Then the room was hermetically sealed and he introduced pure air with varying quantities of carbon dioxide gas, of the same quality as ordinarily encountered in practice. and as near as possible to that as expired by human beings. The air was kept perfectly quiet in the enclosure under the first experiment. Under the second experiment the air in the room was kept circulating by means of a fan, and it was found that, whereas in the first experiment the effects of the CO_2 gas, when it reached above the normal amount which the man within the enclosure could assimilate, manifestly more of the CO_2 gas could be introduced under the second experiment when the air was kept in motion. In other words, the process of "fanning" or keeping the air currents moving within an enclosure without the introduction of any fresh air was found to make it possible for a human being to assimilate greater quantities of the CO_2 gas than he could if the air were quiet.

In the first place, Mr. Hill placed small animals in a sealed box having no portholes and no ventilating ducts—just solid walls of glass—and in these boxes he placed electric fans to churn the air. No fresh air could come in, and no foul air could get out..

While Mr. Hill's experiments were not for the primary purpose of showing that so-called ventilation was necessary, the experiments did show that it was necessary to keep the air moving in order to keep it wholesome. There is no theory about this, inasmuch as the temperature of the healthy human skin is about 98 deg. Fahr.; the air in touch with the skin under the clothes is about 95 deg.; the temperature of the air in the room is usually in the 80's or below, and seldom passes 92 deg. Therefore the fanning blows the hot air away from the skin and puts cooler air in its place. Moreover, fanning blows away chemically dirty air which is shed by the body waste, and replaces it with chemically cleaner air. For this reason a drafty room is a healthy room, and a windy city is a healthy city.

Within a few weeks the commission will conduct extensive experiments along these same lines. The experiments will go somewhat farther than those of Leonard Hill, inasmuch as temperature, pulse and blood pressure conditions will be carefully noted. The effect of air temperature and humidity relatively under stable and varying conditions will also be observed.

Unfortunately, up to the present time no comprehensive experiments of this kind have been made. Fortunately, the commission has in its membership four physicians, so that the physiological effects can be very carefully noted. The experiment room will be proportioned exactly to the fan which is to be used, and among other points to be determined will be the maximum and minimum amount of air to be supplied, the velocity of the air, the horse power required, or the electrical current consumption; in fact, all of the physiological, mechanical, and economic data will be collected in full.

The principal objection at the present time to mechanical ventilation is the great cost of maintaining it at its highest efficiency. In order to do this it has been necessary to install apparatus which we think would give, theoretically, the results required. The experiments, therefore, at the present time by the commission are along the lines of ascertaining the exact requirements for perfect ventilation without the necessity of the added cost of getting positive results by introducing larger amounts of air, and consequently larger apparatus and higher cost units than are necessary.

The second important finding of the commission was to the effect that relative humidity is one of the most important factors in both heating and ventilation. The normal humidity of the external atmosphere varies from 40% to 75% saturation, and if humidity exceeds these limits to any great extent the sensations experienced are unpleasant. The question of what relative humidity should be maintained in rooms is somewhat unsettled, and authorities differ in opinion on this subject, but in actual experiment the commission has found that there are certain fixed standards between temperature and humidity.

Experiments were conducted along this line and results obtained which were somewhat at variance with the theoretical knowledge on this subject. Assuming that we desire to maintain 50% relative humidity at 65 deg. Fahr., then if the outside temperature is zero the corresponding absolute humidity in outside air in grains per cubic foot would be 0.24, and the relative humidity of air when heated to 65 deg. Fahr. would be 3.5%, and the grains of moisture necessary to be added to the grains per cubic foot to maintain 50% relative humidity at 65 deg. would be 3.15. As the temperature of the outside air rises, the corresponding absolute humidity also rises, as does the relative humidity, and the number of grains of moisture necessary to be added naturally decreases. That is to say, if the outside temperature is 10 deg. Fahr., and the assumed relative humidity is 50%, the corresponding absolute humidity of air when heated to 65 deg. Fahr. is 8%, then the number of grains of moisture to be added per cubic foot to maintain 50% would be 3. If the assumed temperature of outside air is 50 deg. Fahr. and the assumed relative humidity of outside air is 50%, and the corresponding relative humidity of outside air in grains is 2.04, then the relative humidity of air, when heated to 65 deg. Fahr., would be 3.1, and the number of grains of moisture to be added to maintain 50% would be only 1.35.

The object of giving this to you is to show, if possible, that there is a relation between the temperature and the humidity. I bring this to your attention, inasmuch as in ventilation (I am taking it for granted that you understand by the term ventilation, artificial ventilation) it is necessary to supply the humidity by means of the ventilating system to maintain the proper amount of such humidity in the room artificially heated. Ventilation and heating are two separate problems and should be so treated in ordinary practice, and inasmuch as the rooms are artificially heated, obviously the best method for introducing proper humidity would be through the air introduced into the room through the ducts.

I will not attempt to describe the different methods of getting proper humidity, but thus far the introduction of humidity in a very fine gaseous form, such as steam, has been found the most efficient. In our experiments at the Normal School in Chicago on the temperature most suitable for the comfort and health of the pupils, we found that we could lower the temperature considerably by raising the humidity within certain limits. Following is a statement by Professor John W. Shepherd, a member of the commission, on this subject.

> "A certain room was taken in this school, 24x32, with a 13 foot ceiling."

In the original installation, Professor Shepherd states,

> "Air entered the room at the ceiling in the center of the east wall. The main air current was across the room from the east wall to west or outside wall, then down the cold outside wall and back to the outlet duct to the floor in the east wall.
>
> "The changes made in the room were as follows: First the outlet duct near the floor was closed, then an air-tight floor laid 18 inches above the regular floor of the room and a false ceiling hung about 18 inches below the ceiling. An air shaft was constructed to connect the inlet duct of the original installation with the air between the floors. The outlet duct was tapped near the ceiling, connecting it with the compartment between the ceiling and the false ceiling. Three-inch circular holes were cut through the false floor and galvanized iron pipes fitted into these openings and let into the duct to within one inch of the bottom of the desks. Openings were also made through the false ceilings so that the air delivered into the room might move on through it."

That is, the floor was bored with these 3 in. holes under each desk and the galvanized pipes brought up within 1 in. or 1½ in. of the bottom of the desk, so that the air was distributed to each child. Some of these ducts were taken along the top of the desk so that air blew along the lines of the hand and others were tipped up so that the air blew into the face of the pupil direct. This was merely as an experiment to see which was most comfortable for the pupil.

It will be noted that these changes turned the operation of the plenum system upside down. Instead of the air entering at the ceiling and leaving near the floor, the reverse was obtained. The reason for doing this was for the purpose of furnishing a positive distribution of air to all pupils within the room and to take advantage of the heat liberated by them in the production of upward moving currents. The experiment was carried on to obtain data on the distribution of the amount of air delivered, and the direction of air current. It was found that the air distribution to each desk and the movement of the air in the room was upward and quite uniformly so.

Experiments were made on the source of contamination of the expired air of the pupils, but primarily for the purpose of determining the general requirements of ventilation and especially to determine the temperature and humidity in relation to the comfort of the pupils. The accepted theory was that 68 to 70 deg. is the best temperature in a room, and that 70% of realtive humidity was the proper and most desirable under the circumstances. Both of these conclusions were theoretical. By charting what was known as a comfort zone, in which different temperatures were taken and the humidity at these different temperatures, and ascertaining from the pupils when they felt comfortable, it was found that there was a temperature and humidity range in which the occupants of the room were comfortable and a different range gave rise to what Professor Shepherd called the "comfort zone." By this term he means to convey that

> "There was a maximum temperature with a minimum relative humidity, and a minimum temperature with a corresponding maximum relative humidity between which limits the occupants of the room were comfortable."

In other words, there seems to be no best temperature, and also no best relative humidity; but the maximum temperature at which one is comfortable will be assured with a minimum relative humidity at that temperature, and the minimum temperature for comfort must have a maximum relative humidity.

Under these conditions it was found that a temperature of 64 or 70 deg. with a corresponding relative humidity of 55 to 30% seems to be the limit. That is, the comfort zone was between 64 deg. temperature and 55% humidity and 70 deg. temperature and 30% humidity. Notice especially that with a temperature below 67 or 68 with a proper relative humidity the pupils were better able to give attention to their work than if the conditions were otherwise. Increased efficiency is what the whole world is striving for at present, and if we can get a temperature at which we get more efficiency and can get it readily and easily as by the introduction of humidity, I see no reason why we should not work on that basis and get good ventilation at the same time.

The experiments even showed conclusively that with the temperature as low as 64 deg. and a relative humidity of 47% an almost ideal condition was created for the majority of the pupils.

There are a number of considerations to be observed in ventilation: namely, that all air for this purpose should be clean air, and that the source of the air for ventilation purposes should be as free from contamination as possible; that in all ventilation work the outside wall and window chill is a factor which cannot be overlooked, inasmuch as both of these create a temperature at the floor level which will be several degrees lower,—in fact, as much as

6 deg. lower,—than the breathing zone temperature, and one quickly perceives a feeling of discomfort; not that the room is really cold, but that at the feet and ankles, which are farthest from the heart, there is a sense of cold compared with the heat at the breathing zone and the result is a feeling of discomfort, or, as we call it, chilliness. Man's heart is farther from his extremities than is the case of other animals. That is the reason, to a great extent, why the feet get cold quicker than any other part of the body. The heart is pumping blood to these farthest extremities and any difference in the temperature of the room is much more perceptible at the extremities than at any other part of the body, and what we get is the psychological sense of discomfort rather than a real sense of discomfort. In other words, if the air at your head was 72 and at your feet 68 or 66, and 66 with the proper humidity at the head would be perfectly comfortable, the contrast between the temperature of 72 at the head and of 66 at the feet would make the feet feel cold and give the sense of chilliness, because our feet do chill quicker than any other part of the body. Besides that, we have inured the rest of our body much more than we have our feet. We can stand almost any change of temperature within reasonable limits on our hands, but we have always encased our feet in impervious coverings and that makes them more sensitive. All air for ventilation should be properly heated, properly cleaned, and properly humidified.

With the cooperation of the ventilation division of the Health Department under the direction of Dr. Vernon Hill, and the Municipal Laboratories under the direction of Dr. Toney, both members of the commission, it has been possible to get valuable data on the subject of air contamination and the necessity of ventilation, especially in our street cars and in our theaters.

In the inspection of over 163 theaters in the city of Chicago, much of it made under the direct observance of the members of the commission, conditions were found which made it possible for the commission to formulate certain resolutions which have not only been embodied to a great extent in the Chicago ordinances, but in the ordinances of other municipalities as part of these, for the ventilation of schools and theaters.

The method of procedure in theaters was interesting. Culture plates were made, the number of dust particles in a given cubic contents of air were counted, and standard Agar plates were exposed from periods of five to ten minutes, as the case might be. The plates were then developed to find the number of bacteria, and to discover, if possible, what the prevailing germs were in the expired air. Necessarily the exposures were made for a certain length of time when the theaters were empty, when an audience was present, and immediately preceding the last performance during the evening. From these bacterial counts conclusions were formed as to the proper method of ventilation, the amount of air necessary to be delivered per person, the method of delivering this air, the temperature, and the best construction for theaters, to secure good ventilation.

Some of the things to be considered are that the theater should be an air-tight box to all intents and purposes; that certain quantities of air should be delivered, and certain quantities of air should be taken out. Taking the velocity and amount of air delivered at the inlet ducts, and the cubic contents of the theater, it is a simple matter to compute the number of cubic feet per hour per person which is being delivered, and from the counts on the plates and the general conditions existing when one comes from the outside air to the inside, it is exceedingly simple to get a standard of good ventilation and to base all calculations from this point on the badly ventilated theaters. In every instance where the bacteria count was high, the method of delivery, the amount of air delivered, the general cleanliness of the theater, and the method of ventilation were found to be closely allied.

I have taken data from charts prepared from experiments, giving the number of colonies on plates in 17 theaters in which the exposures were for five and ten minutes, respectively, and noted the CO_2 contents taken both in poorly ventilated and well ventilated theaters. It is interesting to note that of the 17 theaters which were poorly ventilated, on the 28 plates exposed five minutes there was an average bacterial count of 60.78, and that on 24 such plates, exposed ten minutes, there was an average of 102.68, and the CO_2 contents averaged on 12 samples analyzed 20.58 parts. Please note the exact relationship between the CO_2 and the bacterial count here. In the well ventilated theaters on the five-minute plates, there being 11 such plates, the average bacterial count was only 10.9. On the ten-minute plates, there being 6 such exposures, the average was only 17.83, and in 16 samples of air analyzed the CO_2 contents showed only 10.59, which is practically within the safe limits as allowed in ordinary practice.

Relative to the dust count in 27 samples which were taken, ranging from the roof of the City Hall through a range including the council room, different street cars, and the hurricane deck of the steamship Theodore Roosevelt out three miles in the lake, with the exact temperature of each experiment, the relative humidity of the air, the barometric pressure, the direction and velocity of wind taken into account, and the fact that during some experiments it had either rained the night before or while the experiments were being made, we found a variation at the top of the City Hall from 4,580,000 dust count per cubic foot to 8,740,000. In some of our street cars the dust count per cubic foot was as high as 19,600,000. One experiment on the City Hall when it had rained the night before and during the taking of the sample showed as low as 412,000 dust count to the cubic foot—a good example of the efficacy of air washing. Of course, it was air washing by nature, but it was air washing, nevertheless.

You have often heard the expression, "There is dust on the lake." In the experiment on the hurricane deck of the Theodore Roosevelt with the temperature at 87 deg., a relative humidity of 50%, the barometric pressure 29.03, and the wind only 13 miles per hour south (it was not off shore, it was south), in a 20 cubic foot sample there were found 630,000 dust count per cubic foot, due to some extent, probably, to the fact that people were walking around the machine and quite a bit of dust was being stirred up by them from the deck and from their clothing.

I might go on at random with these experiments, especially those on 17 theaters where the data included method of ventilation, the sense impressions, the CO_2 contents, the place in the theater where the observation was made, the exposure of the Agar plates, and in some cases the exposure of serum plates, to discover if possible the prevalence of contagious germs.

In five of these experiments a negative result was obtained on direct smears showing the absence of tuberculosis germs in the air. On none of the serum plates were diphtheria or pneumonia germs found, but there were prevalent what is known to the medical profession as spreaders. That is, the condition was ripe for the spreading of such diseases. In these five ventilated theaters, the first having an 18 in. disk exhaust, the second a 24 in. disk exhaust, the third two 24 in. disk exhausts, all of them were marked under the sense impressions, either as very dirty or full of smoky, foul odors.

With some of the cultures obtained there were inoculated three guinea pigs in each experiment. In the first experiment, two of these three pigs died in two days with no evidence of tuberculosis; in the second, all three pigs died within two days; in the third, the three pigs died in two days; in the fourth, two pigs died in two days; in the fifth, all three pigs died in two days, but in none of these were there signs of tuberculosis. They simply died of the effects of the inoculation and whatever was deleterious.

Let me impress upon you that dirty air kills more people than dirty water, dirty milk, and dirty food combined. Dirty air is the kind found in the closed house, one in which there is no ventilation and where the windows are not opened. The best method of ventilation available to everybody at the least cost is, after all, the open window. It should flood the home with sunshine and fresh air. This is not possible in our theaters and assembly halls, but that does not change the point: namely, that the time to get fresh air, as was very tersely put in the Health Bulletin, is yesterday, today, and tomorrow, last night, tonight, and tomorrow night, all the time; and a good axiom for the amount of fresh air that is necessary is, "Too much is just enough."

You have probably often wondered why there is less disease of the bad air types in southern cities than there is in northern cities. This is due practically to bad ventilation. For instance, in Chicago we live in air which is several degrees warmer than that of the school and living rooms in New Orleans. Scarlet fever and other bad-air diseases, such as pneumonia, diphtheria and mumps, are not so much cold-climate diseases as they are bad-air diseases brought about by conditions that exist in a cold climate.

Let me call your attention to the fact that in every 100,000 inhabitants of Mobile the death rate is 3; in Memphis it is 5.3; in Louisville 9.6; in Chicago 18.4; in St. Paul 30.2, and in Winnipeg as high as 300. They have in the city of Winnipeg epidemics of scarlet fever, and, peculiarly, 60% of the cases are adults and of those nearly 60% die, and in every instance where they have made investigations they have found that the houses have been practically hermetically sealed. It is almost necessary to close the windows when it is 48 to 50 deg. below zero. But the peculiar phase of the entire subject is that in the spring of the year, when Winnipeg has 600 cases of scarlet fever, within a few weeks after the spring weather opens up and the windows are opened, practically all the cases disappear,—that is to say, they are all cured and no new cases appear. I think this evidence is conclusive to every one of you.

It was not conclusive to me until I went to Regina in Saskatchewan, where the temperature goes a good deal lower even than in Winnipeg, to make an investigation of schools at the request of the School Board, and I found conditions that were peculiarly ripe and interesting for the spread of disease. At the time I went, there was an epidemic of mumps and the mumps were accompanied to a great extent by scarlet fever, and vice versa. I found that the air was being delivered into the school rooms at 120 to 125 deg.; that is was being brought in 8 ft. from the floor at one side and taken out directly below on the same wall. The janitors in every one of the seven schools were bragging that the thermostatic control on the radiators had not been in use all winter, in spite of the fact that the temperature had gone as low as 62 deg. below zero. They had all the radiation on the outside wall, under this arrangement, and it was thought that marvelous economy was being obtained for the School Board in not having the radiation turned on at all, although it was all controlled at 72 deg. and they had an excellent piece of apparatus in the basement that had not been used all winter. In these buildings the air was brought in at the street level, carried across an innumerable number of superheated coils directly into the fan, and was then shot up into the rooms. There were no openings in any of the ducts, and it was necessary for me to take a pair of shears and cut a hole in every duct where I made experiments in order to make the test. I hung strips saturated with phenolthalien, which is peculiarly susceptible to alkaline fumes, at the breathing zone. I then threw a towel saturated with strong ammonia into the duct and let the ammonia fumes go into the room to find, if possible, whether there was any air distribution in any of those rooms. I could not get a reaction, keeping those strips wet, in 25 minutes. One in front of the duct four or five feet away turned pink, as all the strips should have done. All of them should have turned pink in two or two and a half minutes. In about 30 minutes I got a slight reaction from them, not from the fact that there was a distribution of the air, but I was getting diffusion due to the superheated air. It was easy to see how the epidemics arose. Half the pupils were asleep with their heads on their arms. They could not even stay awake during such an interesting experiment, and I know how curiously alive school children are. Anything of that sort should immediately attract their attention. Some of them went to sleep under those conditions and the school teachers all complained that they went home at night with severe headaches.

With a couple of thermometers tested at the Normal School for accuracy I made a wet and dry bulb experiment, and could not detect a particle of humidity in any of those rooms. There was the dry air. All the mucous membranes in those little breathing apparatuses were being dried up, because moisture had to be supplied from something, and one can imagine the enormous trip-hammer shock every one of them got when they went from the inside temperature, which was in the neighborhood of 78 to 80 deg. without a particle of humidity so far as any instrument could detect, out into the air where it was 25 to 30 deg. below zero with a humidity consistent with that temperature. It is no wonder that they were enervated, no wonder that their vitality was depleted, and no wonder that these epidemics existed.

Scarlet fever is a cold-climate disease because the air in the houses is hot when the scarlet fever weather is cold. Children are closely housed in cold climates, and the moral is that children should be kept out of hot rooms; if a child is sick with scarlet fever, keep it in as cool, and well-ventilated a room as you would if it were thoroughly normal and well.

The purpose of the experiments which we have been making was to arrive at some conclusive evidence for a good working basis for ventilation along sane and economical lines. I regret that I cannot go into all these points at this time. I would like to refer to many of the resolutions which have been passed and experiments which have been made, but the time will not permit of it. I am particularly anxious to hear from some of the other gentlemen who have been working along these lines.

The commission will be glad at any time to co-operate with any of those who are engaged in this work. I know that I speak for the commission when I say this. If any of you want to go out to the experiment station at the Normal School, I am sure Professor Shepherd will be very glad indeed to show you the work that has been going on and the conditions under which it has been done.

DISCUSSION.

F. E. Davidson, M. W. S. E. (Chairman): This question of ventilation is something that has occupied the thoughts of many of our best engineers and architects for some time. The Chicago Commission on Ventilation has probably done as much in formulating proper methods of ventilation as any other one body. I understand that this commission is a voluntary association, and I think if an arrangement can be made whereby the Western Society of Engineers can be represented on that commission, it will be an excellent thing.

The question of the ventilation of theaters here in Chicago is of great importance. The present building ordinance requires that 1,500 cubic feet of air per person per hour shall be introduced into every theater of whatever class. Some of our friends, the ventilating contractors and others, have attempted to have that ordinance set aside or at least modified very materially, and I think it is due to the influence of the ventilating commission and the architects of Chicago, that the proposed ordinance to modify the ventilating ordinance has been put on the files of the building committee of the City Council, and there is now no prospect of any modification of this provision of the ordinance as far as our theater buildings are concerned.

Prof. J. W. Shepherd (Sec'y, Chicago Commission on Ventilation): We are practically battling between two extremes in the practice of ventilation, so far as experiments are concerned. One is that of obtaining ventilation by the introduction of as much air as practicable into enclosures to be ventilated, and the other is to introduce as little air as possible. Both of these are somewhat historic in their inception. In the first place, the introduction of as much air as is practicable goes back to the experience of people for centuries. Man, like any other animal, has to become acclimated. One of his means of becoming acclimated is to have the air-taking and air-expelling apparatus adjusted to the conditions that surround him. In other words, man for centuries has not been restricted to a little supply of air but he has been getting as much as he could.

In the next place, I think it is common experience that people who are habituated to sleeping in a room with the windows tightly closed and often with window strips on the outside, are found in the long run easily falling heir to tuberculosis and diseases of that kind. Moreover, the remedy that is most used for tuberculosis now is outdoor air conditions. So I submit these facts as a second kind of evidence in favor of as much air as one can get.

On the other hand, there are those who believe that, in a room like the one we are in this evening, for example, it would be possible for an audience to live, I should say, for ten, fifteen, twenty, or twenty-four hours if the room were made air tight, and all that would be necessary would be to put in a fan or two in a corner of the room to stir up the air. Those who hold that opinion, peculiarly enough, go back to the man who first experimentally said that 10 parts of carbon dioxide in 10,000 should be our standard. About 30 years ago, a German made some experiments on a house. The windows of that house were not as tight as they are fitting them today; the doors were not hung quite so well; there was rattling of doors and windows. The heating was done by means of a stove. The air in that house was changed so that the parts of carbon dioxide in the house were about 10 in 10,000. Now, what do we find 30 years from that time? We find that some of our people are hurrying over to accept the doctrine that what we need is recirculated air. This means a restricted supply of air for ventilation. What does this mean in practice? In New York City the ordinance requires but three-quarters, or hardly that, of the air supplied in our audience halls, particularly in our so-called picture theaters. The news of New York's restricted air supply soon reached Chicago. Not only did that word reach Chicago, but it reached it in a practical way. There was a strong effort put forth by some people in this city to cut down the volume of air required for ventilating purposes and there has been a hard, hard fight. The Board of Health in the city has had a hard fight to maintain a standing for the ordinance. Why? Just because some people who were in earnest about the investigation of the question said that possibly we could get along with less air. Then some other people, practical men who wanted to save as many dollars as they could in the installation of ventilation appliances, and so forth, said, "Well, if these people favor that in experiment let us just cut it down in practice."

Now, you men have something to do. I am not a member of the Board of Health and I am not talking for the Board of Health, but I am interested in this city and so are you, and I would urge upon every one of you, whenever you have an opportunity, to throw a good forceful shot in the direction of plenty of fresh air in our theaters.

Whatever the result of these experiments may be, it certainly is bad policy to practice on human beings by the hundreds of thousands when the thing itself is not at all proven.

Why do they believe in this less quantity of air? That is a point I want to call your attention to. Simply because numbers of experiments that have been made have as yet failed to find the substance or substances in respired air that are or may be harmful. I do not see how any of us can say that because it has not been found therefore we will assume it is not, and that we will subject 200,000 people to the actual practice on this negative conclusion.

If I may submit an analogy, I would like to say that the experience of the human race for hundreds of years must after all count for something as a matter of evidence. We have become accustomed to large quantities of air. In hospital practice and in treatment of diseases, even pneumonia, we now find physicians treating serious cases of pneumonia successfully by opening the windows and getting plenty of fresh air. That is a startling thing, when we consider that a few years ago they would almost build a wall around a sick bed in which there was a patient with pneumonia. So it seems as if (all of this experimental evidence to the contrary) the experience of the human family for a long time must count for something.

Probably you men recollect the time when people talked about malarial districts, and by that they meant places where there were pools of water standing all the time, where there was low, swampy ground. During my boyhood days there was such a place some four or five miles from my home and we called it "a malarial swamp." Then it was found that swamps did not cause malaria at all; that malaria was caused by an infection carried around by mosquitoes. Peculiarly enough, it was still later noted that the breeding place of the mosquito is in low, swampy ground. Consequently we returned again to the people. The people were right, in the first place.

I should not be surprised if some time this negative result which thus far alone has been obtained may have to give way to a positive one, and we may again return to the experience of the people. Until it is known that an individual can sit in a small box of air and have it stirred around him without injury to his heart—until they have tried that on four or five generations, 150 years from now—until then I do not want them to try it on me. I am going to stand for as much fresh air as I can get, and, moreover, I call it pretty good life insurance for me to pay a little more to get plenty of fresh air and know that I am going to have healthful conditions accompanying it rather than to save fifty cents a year and live just a few, perhaps ten or twelve fewer, years. I want to stay here a long time and I am willing to do it by paying fifty cents or a dollar a year more for coal or whatever it takes to get plenty of fresh air.

H. J. Thorkelson, M. W. S. E. (Univ. of Wis.): I cannot altogether agree with the last speaker as to the best method of solving this problem. We are very much interested in the problem of heating and also the problem of ventilation but we are also interested in the problem of securing, as economically as possible, the best conditions necessary in our school rooms.

On one point I think we can agree, and that is it is quite desirable to separate the heating from the ventilation problem to the extent that the heating system should be designed to maintain the proper temperature in the rooms at all times and that additional heating apparatus should be installed to heat such air as may be required for ventilation during those hours when ventilation is required, that is, when the students are in their rooms.

We find that in extremely cold days of winter, a great deal of fresh air enters through infiltration about the doors and windows and at that time the discomfort in the room is not nearly as marked if the fans are completely shut down, and a considerable saving of coal is secured by such a change. We have no desire to economize at the expense of health, but if it is possible to economize by recirculation and washing the air, by cutting down part of the fresh air taken from the outside, we hope to do it.

I might say that we are planning some experiments now and I am very much interested in the experiments that Professor Shepherd is conducting. We have also a room of 20 by 25 ft. We will try to repeat some of Leonard Hill's experiments with CO_2 content, and find out the effect of agitation, if possible, and the effect of re-circulation and washing of the air.

I can readily see the advantage of the open window in houses where we have no ventilating system, but we must all agree that with the plenum system or exhaust system of ventilation an open window may entirely defeat the object sought by the plenum or the exhaust system. I appreciate the advantages of the open window and wonder if we are not going to get, sometime, a system of local room ventilation, with a combination of the open window and a fan, possibly, for agitating the air in the room and for securing all the outdoor air necessary in each room in proportion to the needs of the occupants of that room.

The question is indeed a large one and one on which we are diligently seeking for light.

William B. Jackson, M. W. S. E.: I presume that this subject which is before the Society tonight is as universally important to every one, as almost any subject that could be brought before us. Whatever our chief work may be, this subject is of vital importance to each one of us. One thing that most employers of men have learned is that the efficiency of their men runs down with the quality of air which is supplied to them. I learned this from personal experience early in my own business. Owing to rush of work I placed twenty-four men regularly working in three rooms, each room having the dimensions of 12 by 22 ft. and found that the men were uncomfortable, although each man had about 33 square feet of floor space and we kept the windows and the transoms open. Sufficient air did not get into those rooms by natural draft to satisfy the men and we found that they were unable to give as effective attention to their work as should be expected under satisfactory conditions of ventilation. From the business standpoint alone it was necessary for me to find additional space for the accommodation of those temporarily employed men or else to employ artificial means to supply sufficient fresh air.

I feel that any light that we can get upon this subject is unusually valuable to the members of this Society. I have been much interested in what has already been said this evening and hope to hear much more before the evening is finished.

Mr. Davidson: There are a number of theater buildings in Chicago which are ventilated with what is known as the mushroom system, which has an outlet underneath the theater chairs. I refer particularly to the Princess Theater on Clark Street. I have been there a number of times but never when that ventilating system was in operation. The fact is, with that system the current of air underneath the seat is so unpleasant that the patrons of the theater object to it and the theater people are compelled to shut it off. Thus an owner must suit his patrons as well as comply with the ventilation ordinance. Therefore some system must be installed that will not be unpleasant.

Albert Scheible, M. W. S. E.: This has been one of the most surprising meetings that I have ever attended in this hall, and in one way it is one of the most memorable ones, because it seems to be the first approach here to a subject of such tremendous importance; but for a meeting held for engineers it is certainly most surprising to have able men get up and advocate the open-window method. One of them says, "Open your windows. Let in all the air that you can." That is very much like saying that if you want to light a room, flood in all the light that you can; or if you want heat, pile in all the coal you can. My understanding of engineering is that we are concerned with doing things economically, or at least more efficiently than the average man would do them.

As the author has well brought out in his paper, ventilation is concerned chiefly with the supply of air for our lungs (air being the fuel, as it were, for the human body), and with the removal of the noxious respiration products. The latter include both the CO_2 and any noxious products which affect our nostrils and which influence us most directly when they are close to our heads. With open windows on a windy day we may have quantities of air of a quality fit for breathing; it may be moving through the same room with us, complying nicely with the wording of the theater ventilation ordinance, and yet very little of that air current may do us any good.

But our aim as an engineering society should certainly be to try to regulate those air currents so as to utilize them efficiently.

Another thing: the moment you open a window, you are dependent for your effectiveness partly on the difference between the indoor and outdoor temperature and to a large extent on the wind. Now, we can go out on the lake and we can depend for our propulsion on what some people would call the "natural propulsion" of the air (the wind), which corresponds with what others call "natural ventilation" by an open window, but it is too tremendously wasteful for us to depend on it when we want to get anywhere under average conditions. Just so with the window. We may get a strong draft, but very little of it may be effectively applied where we need it; namely, close to the head of the sitting or sleeping persons.

In regard to the interesting experiments which the author and Professor Shepherd have referred to as made along novel lines, are these really so novel? If I remember right, it is about 30 years since Pettenkofer showed that the CO_2 content of the air was a pretty close index to the amount of its content in respiration products. Since that time page after page of articles in German hygienic journals have been devoted to discussing the nature of the deleterious substance which some of the English scientists have called "Kenatoxin," and whether or not the human body also gives off an antidote which some have called "Anti-Kenatoxin," and so on. No doubt the author and Professor Shepherd are familiar with this earlier work in Europe, and in published reports of the experiments made here. I hope the commission will also introduce these European results to the American public.

The Author: I am sorry if I gave the impression that what the commission is doing is absolutely pioneer work. We all realize that there has been a good deal of work done abroad. We are all trying to keep as well posted on that work as we possibly can, but the fact still remains that we are applying ventilation to conditions which exist here in this country, particularly in Chicago. With all the experiments that have been made abroad, we have thus far not been able to adopt any of their methods, because of our different conditions in modes of living. The object of the commission is not to try to bring itself forward in the least as pioneers in the field of ventilation. The real purpose is to take up, as far as possible, the vital questions of the day as applied to our street cars, to our homes, to our theaters, to our schools, and to our assembly halls at large, simply because the health of our people is absolutely foremost and paramount in our consideration. We know that experiments which have been made abroad are very interesting and no doubt of great value, and we are not trying to "beat anybody to it," as the saying goes. We are just trying to do good, efficient work. Every member of the commission furnishes his services gratis for this purpose and to this end. If there had been any exact formulae or any exact data which had been supplied to us by individuals previous to the time that the commission went into effect, I think that we would have had no need whatever of bringing the commission into existence.

Mr. Davidson: I found, in my own practice, that I could not get hold of any accurate data on the proper ventilation of a large auditorium, which would comply with the building code and at the same time satisfy the audience. That is the problem; to comply with the ordinance, furnishing 1,500 cubic feet of air per hour per person, and still keep the auditorium comfortable.

E. N. Layfield, M. W. S. E.: I have no special knowledge on this subject, but I read a few days ago in one of the technical papers some discussion on the use of what are commercially known as ozonizers, and the statement was made that some committee or body of men had condemned them. I believe that the subject was referred to some men who are eminent as engineers and scientists and they gave a somewhat doubtful reply in regard to the matter. I would ask if the ozonizer was considered in connection with the experiments we have been hearing about tonight. I was not at all surprised to hear that carbon dioxide is not the thing that causes the trouble, and I was wondering if this mysterious element that is to be found with carbon dioxide would be influenced in any way by whatever there is in these ozonizers.

Professor Shepherd: I will endeavor to reply to Mr. Layfield, but would like to make an explanation first.

I desire to have it understood that I am not trying to supplement the author's paper or to speak as a member of the commission. My remarks were made simply as a citizen, along with the rest of you gentlemen, on the subject of ventilation in general.

I suppose I was the one that said, "Get all the fresh air you can." I will always say that until I am convinced by direct evidence otherwise. When I say that when one sleeps he should open his windows wide, I am trying to emphasize a thing which I believe every citizen of Chicago ought to practice in his home.

I do not believe in the procedure of shutting off the radiators in our homes, keeping the temperature from running away, and just living in there with the windows all down.

I am aware of what has been done in Europe. I know what Pettenkofer did and a great many others. I know that Pflügge within the last five years has gone on record for more than the second time to the effect that he could not find that obnoxious and injurious substance in respired air. That is the thing that I referred to a while ago. The presumption has been that there is such a thing and he does not even say there is not, but he says he cannot find it. In the same article, however, he says, "Get outdoors as much as you can." He recognizes the fact that because he has not found this substance, it does not follow that it isn't in existence.

I tried to say a while ago that the practice of restricting air supply is trying to be put forth now on the assumption that since such a substance has not been found, therefore it does not exist.

Now as to ozonizers. That subject came up at Buffalo last August, at the time of the International Congress on School Hygiene, when the world was represented. In that meeting there was quite an exposition of the ozone idea by various people. A German experimenter was in attendance at this congress, and many of us know that there is no better method of experimentation than the German method; anybody who does scientific work knows that the Germans are careful, painstaking, and persistent. So we listen to what they say because their conclusions are always based on considerable evidence. This gentleman said, "We have long since discarded the ozone machine as a helper in the matter of ventilation." That is the point of view that has been voiced by many in this country. There is no doubt that ozone is the most active form of oxygen that we have. It attacks things much more vigorously and easily than does ordinary oxygen. There is no question but that ozone is effective in removing the odor of smoke, for instance, in a room. There is no doubt that it is effective in removing bodily odors. But its efficacy in the matter of destroying germs that attach themselves to the little dust particles and ride around from one place to another until they land on somebody does not seem to be very great.

Recently, during a meeting in Dexter Pavilion, an ozone machine was installed and some culture plates, on which bacteria will grow, were exposed. By this method it was found that in front of the ozone machine there were more germs obtainable than at any other place in the pavilion. The reason for that was this: along with that machine, of course, there was a current of air, and you can see there would naturally be more of an opportunity for driving these little fellows against a plate in front of the machine, and they went right through the ozone machine, landed on the plate, grew and thrived. So ozone cannot stand very firmly on scientific experiments as a helper in ventilation, although it is effective in removing odors.

A place where probably ozone is helpful is where they can generate it and get it into contact with the water which one drinks. There is a better medium through which the ozone is enabled to act in the water solution than it can in air, so it is probable that ozone would be a good thing for helping to purify water for drinking purposes.

Mr. Scheible: Mr. Chairman, may I differ from the last speaker on the subject of ozone? As an electrical man, I know that there probably is no class of electrical apparatus regarding which the public has been so misled as on the subject of ozone apparatus, and the results to be expected from the same. Loud claims have been made by certain manufacturers to the effect that ozone would kill the bacteria in the air, which Professor Shepherd along with many others has found to be untrue, because killing the bacteria would require a concentration of ozone unbearable for our lungs. But, as Professor Shepherd has also pointed out, an ozone content of the air is of value in overcoming odors. This fact has an important bearing on the subject of ventilation, for the moment you strike an unpleasant odor indicating the presence of impurities (although insufficient in quantity to have deleterious effect on the human system), there is a reaction, your nostrils immediately act as a sort of regulator and throttle the depth of breath, if not the breath rate itself; consequently, you take in less air and your vitality is reduced. Now, if under such conditions you can have just sufficient admixture of ozone in the air to mask the offensive odors, you promptly restore the breath to a normal capacity and the result must be decidedly helpful.

In regard to the question of open windows, I wish to say I am heartily in sympathy with the movement of the ventilating commission; indeed, I practice the open-window plan myself at home, but only as an inefficient makeshift forced upon us by the present state of our structures while waiting for our architects to help us to more economical or at least more efficient methods of ventilating.

Mr. Davidson: The ventilation commission has established one very important thing, and that is the comfort zone. As far as I am aware, this is the first time that the comfort zone has been so well established. In other words, as I remember the conclusions, a temperature of say 64 to 65 with humidity of 55 to 60, is as comfortable as a temperature of 70 to 72 with humidity of 30. It seems to me that the question of relative humidity with absolute temperature is one of the best things that has been brought out by the experiments made by the ventilating commission.

H. Gansslen, ASSOC. W. S. E.: During the present year it has been brought to my attention that the city ordinances here, as enforced some time ago, worked considerable hardship upon owners and tenants of moving picture theaters and other public halls. As a matter of general information, I should like to hear something about the present status of the ordinances and possibly something about the provisions of those ordinances.

As I understand it, it is necessary to supply to a public hall 25 cubic feet of fresh air per minute per seat. It seems as if this quantity is very large, especially as this amount of air in the coldest winter weather has to be heated from, say, minus 15 to plus 65 deg. Fahr. The hardship that this ordinance works upon the owners of such halls is considerable. In the first place, the cost of a proper ventilating system that will pass the city ordinances is high. I believe that for an auditorium seating about 800 people, such a system will cost several thousand dollars. The so-called mushroom system, complete with a heating plant, may cost in the neighborhood of four or five thousand dollars. Besides this first cost, the operating expenses are naturally very high. The coal consumption to heat this tremendous amount of air from, say, minus 15 to 65 deg. is out of all proportion to the gross income that many of our moving picture shows can hope for and a great many of those owners will naturally be driven out of business if the ordinances in their present form should be enforced.

These few words are of a more practical nature, probably, than the discussions we have heard here tonight.

Mr. Davidson: I will say for the benefit of the last speaker, that, as I understand the present ventilating ordinance as it appears in the building code, owners of public halls and theaters are required to supply 1,500 cubic feet of fresh air per person per hour. I also understand that up to about six months ago no effort was made by the health department to rigidly enforce that ordinance, for two reasons. First, because of lack of appropriation to employ the necessary inspectors. Second, because there was a question as to whether or not the rigid enforcement of the ordinance might not work some undue hardship on certain owners. I am advised that the health department is not absolutely enforcing the present ordinance in connection with certain old existing houses, but I can assure you that for the past six months no architect has been able to get a set of plans approved in the City Hall by the health department for any system of ventilation which did not, on the face of the plans, at least, comply with the requirements of the health department code and the building code. I do believe, speaking impartially and as an architect doing business with all the departments, that there is no department that is striving harder to do what is fair and square than the ventilating division of the health department under the charge of Professor Hill. He is young, conscientious, and anxious to have the assistance of the architects.

As to whether or not it is fair to enforce this ordinance in connection with all the existing buildings, I can only say that I have attended a number of our downtown loop theaters where the system was not in operation at all. I have tested it by lighting a match and holding it at the outlet. There is a moving picture theater on State Street which has no system of ventilation, and it is crowded daily. I am told it is paying a return of $165,000 a year. In such a case as this, where the owner is making $165,000 per year, and where there is no ventilating system whatever, I think the ventilating ordinance should be enforced.

The Author: Unfortunately this matter of ventilation has not been brought to the attention of the masses; in fact, it has been confined to a very few who have studied it from the standpoint of health.

As to the ordinance imposing an unjust hardship on owners of picture theaters, I cannot accept that view, because the theaters are for just one purpose and that is the exploitation of the public. If a man wants a theater he should comply with the ordinances. I want to say, in addition to what Mr. Davidson has just said, that the health department is looking into the matter of theaters that are not properly ventilated. In fact, a test case is being tried now. Mandamus proceedings were started and the doors of that theater were closed because of lack of ventilation.

First and foremost and always, public health and safety is the one factor that must be taken care of by the nation. The only way we can conserve the nation is by taking care of the health and safety of our people. We enact all sorts of laws for working men, we get all sorts of compensation acts on our books. Why? Because the labor union is strong enough to demand that sort of thing and get it, and it is perfectly justified in getting it, because a man's life is worth something more than the mere wages he is getting. He is part of the community and he is part of this country and he is one of the forces that make this country as great as it is. Those who use the opportunity to menace the public safety and its health should be put out of business. If the theater does not pay when the health of the community is a consideration, then close the theater. That is my way of looking at it.

Mr. Gansslen: How do we know, and who does know, that

25 cubic feet a minute per seat is a proper amount of air? How long ago and where was that practice established?

Furthermore, on the Northwest Side and in other poor and densely populated districts of this city, there are many picture-show houses that actually cannot make a living, and have been closed up because they cannot afford to install and operate a ventilating plant such as is prescribed by the ordinances. Downtown on State Street they can well afford to give ventilation according to the ordinance, whether it is right or wrong.

Mr. Davidson: The ventilation ordinance was passed by the City Council two years ago this month. That ordinance was the joint work of committees representing the Western Society of Engineers, American Institute of Architects, the Chicago Architects' Business Association, and many of the contractors' bodies; in fact, I think there were 75 members of the commission that worked on the ordinance for some three years. Numerous public hearings were had and 1,500 cubic feet per person per hour was first adopted in the health department code two years ago this month; but the ordinance has not been enforced, due to the lack of funds to hire sufficient inspectors. Dr. Young is asking for a much larger fund this year. If it is granted, he will enforce this ordinance strictly.

In regard to the cost of this work, I must take exception. At the time this matter was up before the committee on health of the City Council I was there as a member of the committee representing the Chicago Architects' Business Association, and I was instructed to do my utmost to oppose any changes in the existing code. At that time I made a careful investigation by consulting with some of our best known heating contractors and engineers to ascertain what it would cost to properly heat and ventilate a Class 4-c theater —one of those little picture houses seating 300. The average estimate which I received for a heating and ventilating system which would absolutely comply with the existing code for a 300-seat house was less than $1,000. I believe that a system which will comply with the building code, costing only $1,000, will not put any owner of a moving picture house out of business, particularly when I happen to know that the average rent of these little houses is from $125.00 to $150.00 per month for a 300-seat house. Distributed over a term of years, I think the first cost of installation is very small. In a theater building with a trifle under 3,000 seats, the contract alone for the ventilating system amounted to less than $3,000. These figures are given to you for what they may be worth. Of course, the sums mentioned are simply for ventilating, and do not include heating.

Personally I am in favor of enforcing this present ordinance against every house. If the house cannot comply with the ordinance, it should discontinue its operation.

W. W. DeBerard, M. W. S. E.: Nothing has been said by the author about the ventilation of street cars, and I am wondering whether the ventilation commission has done anything with that problem.

The Author: That is too big an order to fill. I am not going into it at all. The commission has done a great deal of work along that line; in fact, this has been one of the principal lines of work, and when the findings of the commission come out you will see that not only has it gone into the question of street-car ventilation but into the ventilation of elevated-railway cars, day coaches, and sleeping cars. As I said, it is too large an order for this evening. I purposely kept away from it on that account.

F. J. Postel, M. W. S. E.: I think there are two phases of the question which have not received the attention in the past which they have merited. The first is the question of distribution.

We have discussed in detail here this evening the amount of air to be introduced per seat in a theater. It seems to me that the question of distribution is equally important. I have inspected some theaters where there was some question as to whether or not the ventilating equipment complied with the ordinances, and found that the apparatus installed was able to deliver, and probably did deliver, the full amount of air required by the ordinance, yet the ventilation was extremely poor. The air was introduced and taken out in such a way that probably 75% of the audience never got near enough to the fresh air to enjoy its benefits.

It seems to me that as long as there is such a radical difference of opinion among engineers as to how the air should be introduced, and how it should be taken out, it would be advisable for the health department to propose some standard based on the results of tests. This would at once draw out a discussion and presentation of figures which would probably lead to a better knowledge of the subject, and a more uniform practice. I believe that until this question of distribution receives the attention that it requires, the requirements as to the "amount of air per capita" mean nothing when based merely on the total amount of air introduced into the room.

The other question which I think has been too long neglected and which should have immediate attention is the question of humidity. I believe that today there are very few ventilating plants which have any provision whatever for the regulation of the humidity. In residences the question of humidity is almost universally neglected. In this respect the matter of open-window ventilation, which has been discussed tonight, really misses the point of regulation of humidity altogether. Undoubtedly the window will be raised only enough to admit such an amount of air as will be heated by the radiation installed before it comes in contact with the occupants of the room. This process of heating lowers the relative humidity to a point far below normal. It is evident then that window ventilation, while an improvement over some conditions, is by no means a solution of the problem. We cannot hope to maintain a proper degree of humidity in the atmosphere during the heating season, unless we provide a definite means of introducing moisture artificially, whether this is a fan-operated installation or merely an ordinary heating system with the usual provisions for taking in outside air.

J. R. Cravath, M. W. S. E.: I have been interested in this question of humidity for some time and especially in the heating and ventilating of the home, on account of some things Dr. Evans has said in the columns of the *Tribune* to the effect that the usual humidity in our homes and school buildings is extremely low—about 15%. Early last winter I got a wet-and-dry-bulb thermometer and began to investigate in my own home. I have not been able so far to get any such low results as have been attributed to the average home. I do not know that the conditions are different in my home than in many others. It is heated with a hot-air furnace and a good deal of fresh air is taken in, because I am very much of a fresh-air crank. The mixture of outside air would tend to lower the humidity rather than to raise it, but I found that the humidity during the winter was almost never less than 50%; it would range from 50% to 70%. I thought perhaps there were unusual conditions, so I brought the hygrometer down to my office, which is steam heated, and while we usually have considerable fresh air coming through the windows, I found similar conditions existed as to humidity in the office.

I think Mr. Postel hit the nail on the head when he said we must look to distribution a little more and to quantity a little less in the ventilation of our large buildings and audience rooms. A case of that kind has recently come under my notice, where there is no question, apparently, about the amount of air moved being sufficient, but, as Mr. Postel says, 75% of the audience do not get that air.

Another problem is to get the proper operation of the systems after they are installed. Here in this room tonight we have probably got an excellent system of ventilation if we had it in operation, but as a matter of fact, this room is now acting as a vent for the overheated and foul air from the Monadnock Block, which is coming through the transom over the doorway.

Ernest McCullough, M. W. S. E.: The use of wet- and dry-bulb hygrometers is understood by few people. I believe many statements as to humidity are made by people who use the inaccurate, low-priced hair hygrometers sold in department stores.

A CAMPAIGN TO PREVENT FIRE

Franklin H. Wentworth*

Presented December 17, 1913.

The awakening of a people to any great economic fact concerning their public or private welfare is always a matter of profound importance. The recognition by our people of the economic significance of the fire waste has been retarded by an attitude of mind bred by residence in a country of apparently boundless natural resources. Those who are born to great wealth and who accept such an environment without original thought, do not usually realize the sources from which such wealth is drawn until a curtailment of the supply precipitates an investigation. The thought to which the American mind has long been a victim, namely, that our natural resources were unlimited, has resulted in the disregard of our created resources as well. The great Northwest has suffered frightfully in the matter of its standing timber. This loss, with slight encouragement from man, Nature herself through the years will attempt to restore. Nature cannot, however, restore the artificial creations of man; and everything which is made for human comfort by man's creative energy requires a similar and sometimes a greater output of energy for its replacement.

The United States Government, Department of Commerce and Labor, shows that the average annual per capita fire loss in six European countries is 33 cents, while the average per capita loss in the United States is $3.00 and in Canada $3.07. Glasgow has an annual fire loss of $325,000. Boston, smaller than Glasgow, has an annual fire loss of $2,000,000. Berlin has an average fire loss of $175,000 a year. Chicago, the same size, averages $5,000,000 annually. The Berlin fire department costs $300,000 a year; the Chicago fire department costs $3,000,000. These figures are sufficiently impressive, but they are not typical of these cities alone; they are typical of the entire United States and Canada as contrasted with Great Britain and the nations of Europe.

What is there in us, in our people, in our character, to explain this? What is the reason for this shameful contrast in the amount of property destroyed by fire? Is the explanation in a sense psychological? I believe it is. We have been born and bred in a country in which our natural resources have seemed unlimited. It is only within the last two or three years that the United States has given any thought whatever to the conservation of its natural resources. But we are now entering upon a new era, and a great deal of attention and thought is being given to this problem.

I think it would be interesting to you to know how we first began to grapple with this problem of fire waste in the United

---

*Secretary, National Fire Protection Association, Boston, Mass.

States, because our struggle is a very recent one comparatively. The National Fire Protection Association is only eighteen years old. Twenty-five years ago the fire record of New England was shameful. You know New England is a manufacturing section. We have a great many large factories and an innumerable number of small factories, and the fire record of certain of these properties was so unfavorable that some insurance companies declined to insure them at any premium which might be offered. So a little group of engineers made an inquiry into the origins of these fires and the waste caused by them, and found that about 60% of these fires could be traced to some specific cause. These engineers conceived the idea that it was not an impossible proposition to segregate these hazards by putting the particular process of manufacture which was dangerous in a fireproof room, so that when 60% of fires occurred they might be extinguished in the room in which they originated. In the course of their investigations they also saw that the floor area in many factories was much too great, much greater than the business required; they then conceived the idea of running fire walls at intervals through these properties and protecting the openings with standard fire doors, so that when a fire occurred it might be confined to the section in which it originated. They also recommended that stairways, elevators and belt openings be enclosed. Thus they got the result of dividing these properties into fire sections—vertical fire sections and horizontal fire sections—so that the fire department could extinguish a fire not only in the section in which it occurred, but on the floor in which it occurred. These ideas are so simple—such kindergarten ideas—that one stands in amazement that it should require an engineering investigation to point out such simple fire prevention structural facts. It was because no one had ever thought of fire prevention. It was as if a fire were considered an act of God, with the starting of which it was impious to interfere.

That delightful English essayist, Charles Lamb, tells a story of how they first began to eat roast pig in China. I don't know why they kept pigs there before they ate them, unless it was to annoy their neighbors. Lamb says on one occasion a Chinese country house burned and some pigs were roasted in the sty. The son of the family returning and poking in the debris, got his finger into some of this roast pig, and having tasted it, allowed it was good. He gave a piece of it to his father and to his brother, and it soon spread throughout China that roast pig was a wonderful delicacy. Lamb says that in less than a month country houses began to burn all over China. Before all of China was destroyed, however, a Chinaman with a little larger brain than his fellows discovered that it was not necessary to burn a whole country house to have roast pig. It was that sort of acute and masterful intelligence, brought to bear upon this problem in New England, that began to reduce her profligate waste by fire.

March, 1914

About this time, from a very simple idea of a perforated water pipe was evolved the automatic sprinkler—the best fire-fighting engine yet devised. We have reports of over 10,000 fires in our Association records, and we have not yet had a fire reported which was not either held in check or extinguished by the automatic sprinkler, unless there was something abnormal about the fire, or some fault in the equipment or the water supply. About 80% of all these 10,000 fires occurring in properties equipped with automatic sprinklers, were extinguished by the operation of ten sprinkler heads or less.

The rapid development and popularity of this form of fire protection was due to the initiative of the New England Factory Mutual Fire Insurance Companies and their leading engineer, the late Edward Atkinson.

As automatic sprinkler protection came into use, the insurance companies began to grant liberal reductions for their installation. But there was then no standard for their installation. The National Fire Protection Association was organized originally for the purpose of making a standard for the automatic sprinkler. In the second year the engineers composing it reconciled their differences and put out a standard. While they were at work on this standard they discovered there were no standards in the United States for anything relating to fire prevention or protection; there were no standards for electric wiring; no standards for fire hose, hydrants, extinguishers, pumps, or for any of the fire hazards. No one had assumed any responsibility for fire protection nor given any thought to standards which might make fire prevention possible. So it was soon recognized that, although beginning in this small way, we had a much larger responsibility than we had at first supposed; and for eighteen years we have attempted to sustain this responsibility. We have been going on year after year maintaining and revising these standards to which the entire country has long since looked for guidance.

When we came to the making of standards dependent for their integrity upon fire tests,—upon reproducing, experimentally, actual conditions in service,—our work would have been halted and our usefulness impaired but for the genius of a single man. Your own city of Chicago was destined to make the unique and vital contribution to this public service by the development of the Underwriters' Laboratories, a testing station having no duplicate in the world. In this remarkable shop, all tests of fire appliances and hazardous devices or materials are made under the standards of the National Fire Protection Association. In addition to this a system of factory inspection is in operation under the Laboratories' direction, by which the public is enabled to buy goods certified to our standards by inspectors present while the goods are being made. Everyone upon whom may fall the responsibility of purchasing fire appliances should familiarize himself with this factory inspection and label service.

The National Fire Protection Association has members in all walks of life. This fact brings us close to the people and their thought currents. We are engineers and special students of the fire waste, the social and economic results of which are often clearer to us than to the Underwriters themselves. It is obvious to us that insurance rates cannot be reduced irrespective of the loss ratio without forcing insurance companies, who mean honestly to pay their losses, to retire. Capital invested in underwriting is not so irrevocably fixed as capital invested in public service corporations using public property or rights-of-way. Such investments can be controlled easily by the state, but capital invested in underwriting can easily seek other channels and withdraw from the states imposing undesirable burdens upon it, thus leaving the business world without the desired indemnity.

Last year in the United States Legislatures of three states, New York, Illinois, and Wisconsin, an investigation was undertaken of the methods and practices of the fire insurance business. This action found its impulse in hostility toward the fire underwriting interests; but all of these investigations developed the fact that scientific or satisfactory underwriting is impossible, and will continue to be impossible, until the criminally careless fire waste of the country is curtailed. It is obvious that these investigations represent an incoherent protest against the frightful impoverishment by the fire tax. The people feel that the fire tax is too high. It is too high! Everybody knows that it is too high. But how can the fire tax be lessened except by attacking the cause of it? This is the question that every representative body must be forced to answer.

The awakening of the American people to a consciousness of their collective responsibility for the fire waste makes the last two years of great significance, especially to that comparatively small body of men who for eighteen years have devoted their thought to the subject, and who have appealed year after year for the attention of the people respecting it. Our waste of $3.00 per capita per annum means that every man, woman, and child pays $3.00 a year for fire waste. That means that the man with the average family, his wife, and three children—a family of five—pays $15.00 a year fire tax. The United States Government in its report adds to this fire waste the cost of maintaining fire departments, which is as much more. This means $30.00 a year to the average family. Now, if on some blue Monday in every year a representative of the Government were to come around and ask us each for our cheque for $30.00 to pay our share of the national carelessness, then we should realize what we pay. But we do not realize that we pay it, because this tax is indirect. The big manufacturers and the big merchants know that this fire expense is a tax. They equip their premises with automatic sprinklers. They put in protective apparatus. They get the lowest insurance rate they can because it helps them to compete; but the man in the street, the ordinary man, does not know how this fire waste is paid. Take wool, for example. Wool in the warehouse is insured—that is a tax. It is insured in transportation, and there it pays a fire tax. It is insured in the textile factory where it is worked up into cloth. It is insured in the clothing store, insured in the tailor shop, in the department store, and all the way along this fire tax is added to the cost, and when you buy a coat, you pay it. Every stock of goods that is insured carries this tax, and it is passed along to the ultimate consumer. The masses do not know that they pay it. They do not realize that when they buy a hat, or a pair of shoes, or a suit of clothes, or anything which goes through the regular channels of industry, production, distribution, and exchange, they pay a tax. Not realizing it, they are indifferent to fire. They think fire does not affect them.

The fire loss in the United States and Canada for the last ten years has averaged $250,000,000 a year. What could we do with that? We could build roads, build canals, improve our harbors, build battleships—if we have no less mediaeval use for our iron! We could do a great many things with $250,000,000 a year. What does that mean? It means $30,000 an hour, $500.00 a minute; it means that every ten minutes we are burning the equivalent of a comfortable $5,000 home. What country can stand a drain like that? Suppose we were to throw into the sea $250,000,000 in wheat or corn or cotton, or lose $250,000,000 out of our two national treasuries. Then we would realize that we were being impoverished by this waste. But we have lost the faculty of being moved by an ordinary fire. In Europe a $100,000 fire shocks the entire country. All the papers in Continental Europe comment on it, wanting to know how it occurred, who was responsible for it, whether the conditions obtaining in the city where it occurred can be found elsewhere, so that such a fire might be duplicated. But here in America, if we take up the morning paper and do not find two or three $100,000 fires recorded we think it has been a dull evening!

We are the most careless people with matches on the face of the earth. In Europe, if you want matches you have to go where they are kept. In America matches are everywhere—on our bureaus; in our desk drawers; on the mantlepiece; library tables; in all our old waistcoat pockets in the closet; if we wake up in the middle of the night and reach out and cannot find a match we feel insulted! Every match is a potential conflagration. There is no reason why any man who loves his family should have any match in the house except the match which lights only on the box. These strike-anywhere matches, if they are dropped on the floor and stepped on, will frequently ignite the skirts of women. This match is particularly dangerous to the child. The child is an imitator. He sees his older brother or his father or mother light a match. That is a dramatic thing; it is going to stick in his mind; he will remember it until he can get hold of one of those little fire sticks and see what he can do with it; and perhaps burn his little body. Every week dozens of clippings on this very subject come to my desk, and it seems to me my visit to Chicago would be worth while if the gentlemen here tonight who have young children will henceforth have no matches in the house except those which light only on the box.

The fire waste touches the pocket of every man, woman and child in the nation; it strikes as surely but as quietly as indirect taxation; it merges with the cost of everything we eat and drink and wear. The profligate burning every year of $250,000,000 in the value of the work of men's hands means the inevitable impoverishment of the people. This fearful loss, spread over the entire business world of America, is beginning to manifest its impoverishing blight. The people feel it without yet being awake to its cause. Their awakening is retarded by the prevalence of the foolish notion that the insurance companies pay this colossal tax. But how could they, and remain solvent? They are mere collectors and distributors of that portion of this tax which is represented by their policies. Half of it they never touch; it falls upon the householder direct. San Francisco and Chelsea do not pay for themselves. You in Illinois and we in Massachusetts help pay for them. And next year San Francisco and Chelsea, risen from their ashes, may help to pay for your cities and ours. There is one way in which we can escape the periodical paying for one another, and that is for us both to begin rational building construction and then protect what we have builded against fire.

It is the ever present conflagration hazard which makes any approach to scientific underwriting impossible. The conflagration hazard is not confined to any one state. It is present in every state and in every city and town. We have built largely of wood, and sooner or later we must pay the penalty unless we can find some way in which to protect our cities.

There is a way to solve this conflagration problem—not absolutely, but at least relatively. You cannot be expected to tear down your cities and rebuild them of fire-resisting material; the cities must be protected as they stand. In the heart of nearly every city there are streets crossing at right angles, along which for a very considerable distance are buildings of brick, stone and concrete. This shows a more or less complete Maltese cross of buildings which are not wooden and which operate to divide the wooden-built district into quarter sections, and which might hold a fire in any one of these sections if they were equipped to do so. These brick and stone buildings are ordinarily valueless as fire-stops, because their windows are of thin glass and their window frames of wood. At Baltimore and San Francisco the conflagration attacked such buildings easily, breaking out the panes, consuming the frames, and converting every story of these brick structures into horizontal flues full of combustible contents. Brick and stone buildings are logical and capable fire-stops if the fire can be kept out of them. The small city that will trace out its Maltese cross of such buildings and equip them with metal window frames and wired glass will immediately possess the equivalent of substantial fire walls crossing at right angles in its center, dividing it into four sections. By such a simple, inexpensive, but yet strategic procedure many a city may save itself from the destruction which now awaits only the right kind of a fire on the right kind of a night.

I have referred in this plan merely to the smaller cities, but it is obvious that this form of protection is equally imperative in the brick, stone and concrete districts of all large cities where great values are housed in close proximity. Fires in the large cities entail an enormous waste because of the great values assembled there. We must come eventually to the equipment of all commercial, factory and office buildings with metal window frames and wired glass. This will mean the abolition of the conflagration hazard in our cities. Fires will then be unit fires, extinguished easily by a competent fire department within the building in which they originate; for the protection of window openings not only prevents fire from entering, but prevents fire from issuing out of the burning buildings. We may expect an occasional exceedingly hot fire to break down the defenses of an adjoining building, but it is obvious that a conflagration could not get under way among buildings of fire-resistive construction with properly protected window openings.

Having thus fortified city buildings one against the other, extensive fires within individual structures can be prevented by the use of the now well established automatic sprinkler system. The automatic sprinkler applies the water without the help of human agencies while the fire is still incipient. It will operate in a dense smoke as well as in a clear atmosphere. It will not throw excessive deluges of water in wrong places as the fire departments are continually forced to do. With our window openings protected and our buildings equipped with such extinguishers, the conflagration hazard in mercantile districts will be eliminated. There will then remain for consideration our immense residence districts constructed almost wholly of wood surrounding the mercantile centers, like faggots around a funeral pyre. We can lessen the loss here by the abolition of the use of wooden shingles.

The prohibition of the shingle roof, which is now generally recognized as a conflagration breeder, is today almost universal within city fire limits, and from the more enlightened communities it is excluded altogether. Burning shingles can be carried great distances by the wind or draught of a conflagration, and when they may alight in their turn upon other dry shingles, they make fearful havoc.

It will not be necessary to remove all shingle roofs immediately. An effective city ordinance might require all roofs constructed in the future to be of incombustible material, and that all roofs which shall hereafter require repair to the extent of one-third of their area shall be replaced with incombustible roofs. The modern shingle is thin, and the machinery which now makes it leaves a fuzzy surface which, after a period of drought, becomes like tinder. Without shingle roofs flying brands would not be carried over the brick centers of the city by the wind.

Outside of the abolition of the shingle roof, we must look for the protection of our homes to the corrected habits of our people. We must look carefully after the heating apparatus of our homes, giving them the constant and necessary attention demanded by receptacles containing fire. The building of proper flues and chimneys is especially necessary in connection with residences. Then we must have a general revision throughout the country of our building codes. We must stop the erection of a certain shoddy class of building and we must limit the height of all buildings. In Boston we limit them to 125 feet. There is no reason why cities that can expand, and which are not bound by physical barriers, should follow the example of New York and erect these absurdly high buildings. They inflict an enormous expense upon the city for fire protection.

There are other matters, however, to which we must give proper thought. Among them is the best use of the fire-fighting agencies which have been established and which are maintained at a great cost by our people.

The mental habits of a people are a vital factor in affecting social progress. It is the mental habit of our people to assume that fire departments are maintained for the exclusive purpose of extinguishing fires. It is obvious, however, that fire departments have large possibilities for service in preventing fires; a service which is, I regret to say, yet largely potential. Every fireman, from the chief engineer down to the drivers and pipe men, should be regularly detailed for inspection service. Three or four hours a week for each man, going to basements, attics, courts and alleys, keeping down accumulations of rubbish—which spring up over night—locating the storage of inflammable oils and explosives would keep the city clean of its most persistent fire dangers. Every fireman should in turn cover every section in the course of six months. One would thus check up the inspections of the other, and local conditions would become a matter for educative conversation about headquarters.

There is, however, a most important result to be achieved by such an inspection system over and beyond keeping the city clean: and that is the education of the fire-fighters in the exact physical character of the city. To know exactly which passageways are open and which are closed; to know which are fire walls and which are not; to have a mental picture of the exposures, the windows, the roof openings, the cornices, and all the other physical details important in fire-fighting, would so heighten the team work of a department that, like expert swordsmen, they could make their thrusts without loss of time straight at the vulnerable part. There are a few cities in the United States where such practice, partially in effect, has already demonstrated its singular efficiency. The citizens of every town and city should demand this sort of service from its fire department.

Then we must begin to place the responsibility upon the individual for fires. It is difficult to do that, I know, and yet it can be done. In France, if you have a fire and that fire damages your neighbor's property you have to pay your neighbor's loss. That is very educative! It would be a very good thing if we had such a law in America. We can fix responsibility, however, and we can change our attitude of mind towards the man who has fires. When we look upon the man who has a fire as one who has done an unneighborly thing, as one who is a public offender unless he can prove that he was in no way responsible for that fire, then we will have begun to make headway. We must have inquiry into the causes of all fires, not merely an inquiry into the fire which is suspected to be the work of some incendiary. Nearly every fire is the result of some carelessness; and the careless man must be held up to public criticism as a man who has picked the pockets of the rest of us; because that is what it is in its last analysis. When we get fire marshals in every state or province who shall inquire into the causes of fires, I believe we will begin to correct our personal habits in respect to the things that cause fires.

But all the educational work necessary to achieve these desirable results cannot be done from afar. You must grapple locally with local problems and local needs. Every city has its own peculiar conditions. With this thought in mind, a Chicago Chapter of the National Fire Protection Association has just been organized with an architect and engineer as president, Mr. Frank D. Chase, who for some years was chairman of the fire prevention committee of the Chicago City Club. Your Society will naturally be called upon to aid in this great work which shall coordinate all Chicago efforts in the direction of fire prevention. It is the beginning of a great public service of profound importance to your city, and the nation.

The American people are not dull in comprehension, nor are they slow to act once the necessities of a situation are made clear to them. The awakening of the present year manifested by the observance of "Fire Prevention Day" in many of the cities of the United States, by the appointment of fire marshals, and the amendment of fire marshal laws, and by the teaching of the fire hazards in many public schools, indicates that we as a people will not much longer tolerate our pitiful impoverishment by fire waste. It is true that so long as our wooden cities stand they must occasionally suffer disastrous fires with, oftentimes, shocking loss of life; but with the growing disposition to hold our citizens personally responsible for their carelessness before the bar of public opinion, many of our most prolific causes of fire will disappear.

Our civilization grows daily more complex. Every man's life is becoming more inextricably linked with the lives of others. An injury to one is increasingly an injury to all. Out of a proper realization of these facts is coming a larger sense of civic responsibility. As citizens of a common country and brothers of a great international family, we may some day evolve a civilization in which there shall be no waste and in which the thought of the common good shall be the profoundest impulse in the hearts of our people.

DISCUSSION.

F. E. Davidson, M. W. S. E. (Chairman): The address to which we have listened shows, in a slight degree, the work of the National Fire Protection Association, whose headquarters are in Boston.

Engineers in general have not, in the past, given the question of fire protection the attention which it merits, due, perhaps, to the fact that they prefer to leave these problems to the architect to wrestle with. It is a subject which seems to interest only those who are actively engaged in building work.

I think that our rate-making bodies are, to a very large extent, to blame for the exceedingly high fire-loss rate in the United States. In discussing the matter with the author, I called his attention to an instance in my own practice. Recently I presented to the Chicago Board of Underwriters, the rate makers, plans and specifications for a factory building which will be constructed in Chicago at an early date. The building will be practically joist construction, and will cover a large ground area, something like 65,000 square feet. The owner, having in mind the financial stringency, instructed me to design the building with a view of its being erected as cheaply as possible. He did not want to spend a dollar he did not have to; at the same time he wished the building to be protected against undue fire hazards. I was astonished to get a rate less than 11c per $100.00 per year on that type of construction. I then asked what the rate would be if the building were erected absolutely fireproof, and the reply was, 10c. That is one instance where the rate makers are actually "premiumizing" the cheapest class of building construction.

That is true not only of the Chicago Board of Underwriters, but of every other rate-making board in the United States of which I have knowledge.

As another illustration, yesterday a client sent for me and said, "I propose to construct a five-story building on a certain lot. Personally I would like to build a fireproof building, but can you show me where it will pay me to do it?" I sat down and figured for two hours, figuring not only the first cost but the depreciation and maintenance,—three items which govern,—and I could not produce figures which would show that it would pay him to build fireproof.

In my opinion, the reason for our exceedingly great fire risk is not due to the architects, because an architect must do as the owner of a building desires, to a large extent; if not, the owner will get someone else who will. But the rate-making bodies have it within their power absolutely, in my opinion, to very largely govern this question of hazard by fixing the rates accordingly and giving an owner a premium on a high class construction.

I think the rate-making bodies should penalize old fire traps and cancel insurance if elevators and stairways are not properly enclosed. If the National Fire Protection Association, having the relationship which it has with the National Board of Fire Underwriters, could influence these rate-making bodies to cancel these bad hazards, I have no doubt that in a very short time the general fire risk of a great many sections of our cities would be greatly reduced, and owners of fire traps would very soon put such buildings in proper shape.

We have with us tonight Mr. J. C. McDonnell, Chief of the Bureau of Fire Prevention and Public Safety, and his assistant, Mr. E. W. Case, who are endeavoring to enforce the rules and regulations of the bureau. We would like to hear from them.

J. C. McDonnell (Chief, Bureau of Fire Prevention): I am glad to have had the privilege of listening to the address which has been given this evening. The Chicago Bureau of Fire Prevention is following, in as nearly a practical way as it is capable of doing, the gospel of the National Fire Protection Association.

I wish that such an address as we have had this evening could be given before the Chicago City Council, and also before the Chicago Fire Department. I have served a good many years in fighting fires, helping scatter a lot of water around, breaking crockery, glassware, and so forth, and the thought often came to me that a great deal of the work was wasted energy, and that much of it could be saved by some method of fire prevention. We have a comprehensive ordinance to follow, and are doing the best we can. When I said I would like to have the author of this paper address the Chicago City Council, I had in mind the fact that some of the men who voted for the ordinance, came into our office after the ordinance had been passed, and expressed themselves as wondering what was the matter with them when they voted for such an ordinance. It makes a lot of trouble with their constituents.

Mr. Case has 108 cases in court tomorrow morning, but that is not a large percentage considering that we have made approximately 9,000 inspections thus far this year.

We are working in coöperation with the fire department as far as is possible at the present time, and the men that come into the bureau from the department, as inspectors, are active firemen, men who have submitted themselves or have taken the examination for the first step in promotion in the department, that of lieutenant. They are sent to us in civil service order, and it will be but a comparatively short time when nearly all of the officers of the department shall have gone through this bureau and shall have had the advantage of this technical training as inspectors.

The bureau also has a school. We have a class every Monday morning in the public hearing room of the City Hall for those who wish to come. Typical plans of buildings are drawn on the blackboard, and the firemen practice on them. Instead of an almost meaningless report which we have heretofore been getting from the various officers of the department, one of those inspectors now makes a report. The complaint appears on the face of the report, and on turning to the back of the sheet we find a picture of the building. The floor plan is depicted, the dividing wall, the end walls, open stairs or closed stairs, dummy elevators, and things of that kind.

So by coming to us these firemen have the advantage of this technical training, then they reënter the department as officers, as lieutenants. This training has created enthusiasm among the men, and as a result, instead of finding the men playing checkers and dominoes and reading dime novels and the Police Gazette during their spare time, you will probably find them reading a paper on fire protection, safety engineering, and other such matters. I think that reason alone is sufficient for the existence of the bureau.

Through the requirements of the law we are conducting fire drills in various classes of buildings. Mercantile buildings in which a certain number of people are employed above a certain floor,—second, third, fourth, or fifth and so on up,—department stores, and the schools, are required to have fire drills. We have helped along in distributing literature on fire prevention day. I was very much surprised, shortly after October 9th last, to see in the public press a statement emanating from the superintendent of schools to the effect that if the fire drills and fire prevention days and fire lessons continued they would have to eliminate the three R's in the schools.

The bureau is yet in its infancy. Next year we expect to have a larger force than we have this year, and I think that in the course of a few years Chicago will have an excellent fire prevention bureau. As the author said, the country is waking up to the fact that an ounce of fire prevention is better than tons of water. I would not for an instant suggest the curtailing of fire protection; we must have the fire-fighting forces, because fires will occur in spite of all we can do: but I am of the firm belief that if 5 to 10% of the money expended on fire extinguishment were diverted to fire prevention it would accomplish much greater results.

E. W. Case (Bureau of Fire Prevention): I simply want to say that I believe we have in the fire prevention ordinance of Chicago one of the best ordinances, if not the best, of the kind in the

United States. It takes care not only of the new buildings of various types of construction, but also gives the Bureau power to correct defects in old buildings.

I believe the author gave us the crux of the whole matter when he impressed upon us the necessity of educating our citizens to know what the fire loss of the United States means to the individual. Until that condition is brought about we will have more difficulty in enforcing the ordinances passed by the cities or the states.

Mr. Davidson: We would like to hear from Mr. Robinson, Chief Engineer of the Underwriters' Laboratories, located in Chicago. Mr. Robinson is also a member of this Society.

W. C. Robinson, M. W. S. E.: I am not very well prepared to speak, but one thought brought out by the author relating to the engineering side of the fire-protection and fire-prevention problem ought to be emphasized. I refer to the question of preventing any fire which may start from becoming more than a unit fire. If every property owner did his full share in preventing the horizontal travel of fire in cities, particularly in congested districts, the conflagration hazard, that undeterminable element mentioned by the author, would not exist, and we would be in a position to establish methods more closely approximating those of the life insurance companies.

The first time I heard this question mentioned was in an address delivered by U. C. Crosby in Milwaukee, a good many years ago. This thought impressed me very much at the time. It also impressed me strongly during a visit to San Francisco after their fire when I was much surprised to find the prevailing impression that the installation of high-pressure water pipes several blocks apart would serve as an absolute barrier to the spread of fire in certain portions of the city filled with frame buildings.

It should have been known, particularly in view of the experience through which the city had just passed, that such an arrangement would not work out the salvation of the city so far as the spread of fire was concerned, for the reason that the protection was not carried close enough to the units and that fire could easily involve a great many units and gain headway which would render the proposed protection ineffective.

As the author said, there is not much hope for a frame city under some conditions. At the same time, if high pressure systems are able to furnish the tremendous volume of water which may be required under such conditions, and the system is brought close to all of the units, the danger of the conflagration will be greatly reduced, if not practically eliminated.

In our metropolitan districts the aim should be to prevent fire from becoming more than a unit fire. If a man builds a building, no matter what the building may be, he should be obliged to provide the necessary safeguards against the horizontal spread of fire. The cost of doing this would be largely proportionate to the hazard he creates, that is, the man having the smaller property would naturally not have to spend as much as the man having the larger property. The costs may not be in direct proportion but would probably be in a large measure proportionate to the respective hazards created, and would seem to justify a general requirement. This is the most effective way of coping with the conflagration hazard I have been able to discover.

The author spoke of fire fighting at a given number of stories above street level. Next to the automatic sprinkler system, the standpipe and hose system furnishes the best means of coping with fire under such conditions. It can be made to embody practically every feature of the sprinkler system except the automatic feature. The present method of installing and using such systems in no wise takes care of the situation; that is, the standpipe and hose system is as yet not fully developed, is not fully or properly equipped, and, as a general thing, is not effectively used. I think that Chief McDonnell and perhaps others here appreciate this. The authorities in the city of New York have been obliged to recognize the importance of this apparatus, and it is probable that more of these systems are made use of in one month in that city than in all the rest of the cities of the country put together. Reports covering fires in New York where standpipes are used are sent to me periodically.

If the standpipe system is as well designed and equipped as any other apparatus the fire department is called upon to use, it may have a much greater scope than the protection of the building in which it is installed. Streams from the standpipes in one building may be brought to bear on fires in adjoining or nearby buildings where the burning stories are otherwise inaccessible to firemen. If your fire-fighting equipment is not automatic, you must be able to at least place men within striking distance of the fire. In congested districts having high buildings, the standpipe systems in such buildings would constitute a valuable auxiliary in reducing the possibility of what have been termed aerial conflagrations.

Mr. Davidson: Speaking of protection from standpipe systems, I am reminded of an incident that happened in connection with one of the large office buildings in Chicago a few years ago when a slight fire occurred in the building. It seemed that the standpipe went up the elevator shaft and the contractor bricked all the nipples into the masonry solid, allowing no room for expansion. Fire invaded the elevator shaft and they tried to use the standpipe and hose, but the nipples were all broken off at the riser.

Another interesting item of statistics: I was told some time ago that if there should be a general conflagration in lower Manhattan and it was a total loss, there is enough insurable property there covering an area of about three-quarters of a square mile which, if the insurance companies had to pay it all, would require every available dollar in the United States. That gives an idea of the insurable value of the contents of a very small area.

THE CEMENT GUN AND ITS WORK

CARL WEBER, M. W. S. E.

Presented March 9, 1914.

INTRODUCTION.

The Cement Gun is a machine invented about six years ago for the purpose of "shooting" a coating of cement mortar or the like onto construction surfaces, as, for instance, on concrete, brick, tile, wood and steel work.

The Gun is operated with compressed air. The mortar is deposited in a uniform coat with so great a force that it not only adheres to new and old surfaces with utmost tenacity but it also expels by its impact all superfluous air and water, and in this manner becomes so dense that it is an excellent waterproofing medium.

If used on interior or exterior wall surfaces the finished product resembles cement stucco and, as a matter of fact, the original purpose and the first work to which the Cement Gun was applied was the production of such work. It soon became apparent, however, that the product of the Cement Gun was superior to handwork and that the material displayed qualities which put it in a class all by itself as will be shown later in this paper. Therefore, and in order to distinguish the Cement Gun product from all other classes of cement work, the name "Gunite" was adopted for the same.

The first practical work of the Cement Gun was the covering of the old Field Museum with a coat of gypsum stucco, a highly successful experiment.

Although the first principles were proven to be absolutely correct, the form of the machine and the method of operating it have been greatly improved.

Figure 1 gives a view of one of the modern machines, while in Fig. 2 one of the older types of the machine is illustrated. Between these two forms there were numerous but now obsolete types, of which a few are still in use. The difference in height of the two machines is especially noticeable, also the different form of the hoppers and the arrangement of the air motor.

The greatest advantage of the new Cement Gun is its increased working capacity, which is about three times as much as that of the older type. The light weight of the new Gun and the convenient arrangement of all its working parts also help very materially to reduce the cost of work.

Cement Guns have been used on the Panama Canal, the New York Central Terminal Station, the Woolworth Building, the Croton (N. Y.) Aqueduct, construction of large reservoirs in San Francisco and Nashville, in the Hawaiian Islands, for viaducts in Spain and other work.

The Cement Gun fills an important field in engineering work for waterproofing, protection of steel, the lining of tunnels, reservoirs, shafts, ditches and canals, etc., and the repairing of disintegrated concrete, masonry and brick work. Although there is still a large amount of gun stucco work done on ordinary building construction, the engineering work is now decidedly predominant.

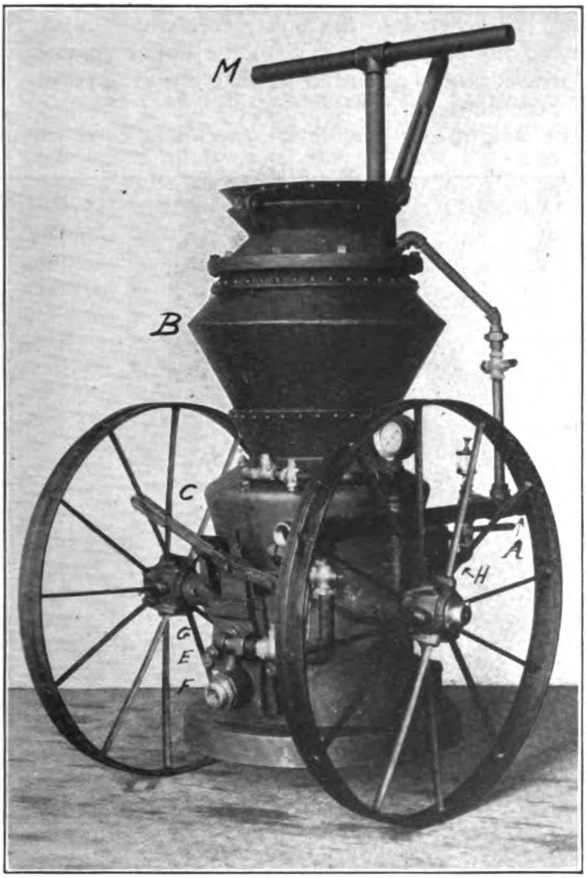


Fig. 1—Modern Type of Cement Gun.

OPERATION OF THE CEMENT GUN.

Figure 1 illustrates the modern Cement Gun in working position; if the same is to be moved, the machine is tilted over and by means of the handle bars, *M,* it is wheeled about like a cart.

The air line from the compressor is connected at *A* to the main air pipe, which by its branches conveys the air to the motor *H,* driving the feed wheel to the lower *C* and upper *B* material hoppers and to the main outlet valve *GEF.* At different points in the air lines the necessary cocks, check valves, oilers, and pressure gauges are provided as shown in the picture.

The operation of the Gun is simple. Fig. 3 shows a vertical cross section. The inside construction and the method of operation are easily understood from this drawing.

The material, which has been previously mixed dry in the right proportion, is thrown into the upper receiving hopper *B* which has a capacity of about 3 cu. ft. Then the upper cone valve is closed and compressed air is admitted so that the air pressure in hoppers *B* and *C* become equal.

By the weight of the material, the lower cone valve opens and admits the material into the lower hopper. Then the lower cone valve is closed. An air outlet valve in hopper *B* emits the compressed air and hopper *B* is ready for another charge.

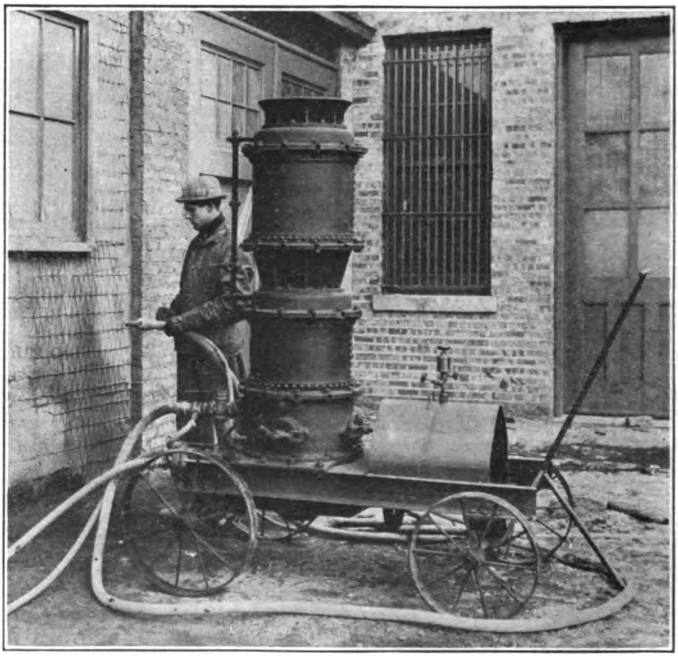


Fig. 2—Older Type of Cement Gun

In this manner the lower hopper *C* is always under equal pressure and continuous operation of the Gun is made possible.

At the bottom of hopper *C* there is the cone-shaped feed wheel *D,* which has a number of small pockets equally spaced on its outer edge. This feed wheel is gear-connected to the air motor *H,* which keeps the wheel in continuous rotation. As the feed wheel rotates, it carries in its pockets measured quantities of material into the stream of compressed air entering at *E*, which blows the material into the delivery hose connected at *F*. The pockets on this feed wheel are so arranged that before the material is entirely fed out of one pocket, the feeding begins from the next one, so that the flow of material is smooth and even. *J* is an agitator revolving with the feed wheel. *K* is the large gear wheel connecting the air motor *H*. *L* is the foot rest and *G* is the shut-off valve with a by-pass which automatically cleans the hose.

With the lower tank full of material, the operation of the machine proceeds as follows: Air is admitted to the air motor which starts the feed wheel in motion; the air line to valve *G* is then opened, but as the slide is closed the air does not enter the machine but escapes through the by-pass in the body of the valve out through the material hose, cleaning the hose and creating a suction which prevents clogging on opening the valve slide; this slide is then opened and the material begins to discharge at the nozzle.

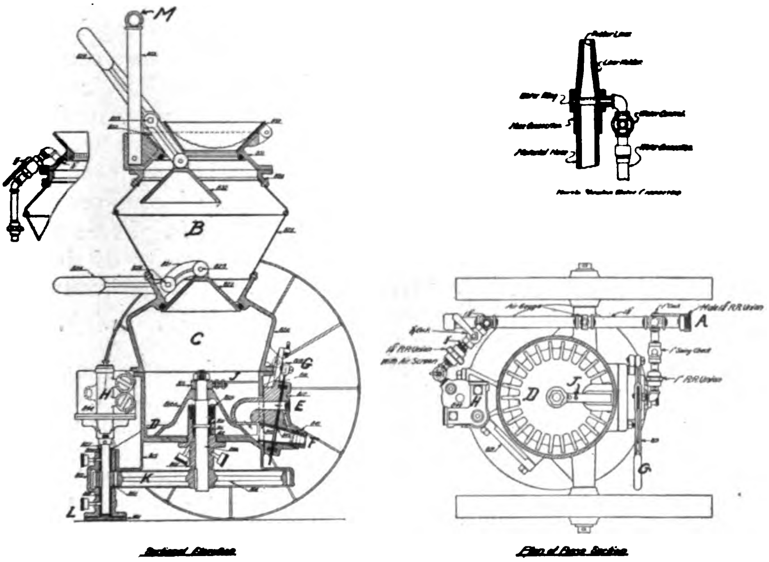


Fig. 3—Construction Details, Modern Cement Gun.

The delivery hose is made of pure soft rubber covered with heavy canvas and may be 300 ft. in length and even more. It is usually made up in sections of 50 ft. each, united by special metal couplings.

At the end of the hose line is the rubber-lined metal nozzle, which is also connected to a water hose in such a manner that a fine spray of water is added to the material as it rushes through the nozzle. A small screw valve enables the nozzle man to correctly adjust the amount of water needed for the proper hydration of the material.

It is characteristic of the Cement Gun, and of greatest importance for the quality of the work, that the material is delivered "dry" through the machine into the nozzle, and that the necessary water for hydration is added at the moment of deposit. The hydration of the material really takes place in the air between the nozzle and the place of deposit and any loss of the binding power of the cement in transit is absolutely avoided. The initial set of the cement takes place on the structure and not in the mortar box.

Another very important factor of the Cement Gun process is that only the proper amount of water for perfect hydration can be added because all superfluous water is expelled automatically by the force of impact of the material at its place of deposit.

If we consider that the air in the Cement Gun does not act as a plunger in forcing the material through the delivery hose but carries the materials by suspension and skin friction, we can easily understand that only a dry material can be successfully conveyed by air pressure and that only a machine shooting dry material can be self cleaning and free from clogging and excessive wear.

The air consumption of the Cement Gun is very economical. An air compressor delivering about 40 cu. ft. of compressed air at 45 lb. pressure, which is equal to about 150 cu. ft. of free air per minute, is sufficient for the ordinary working capacity of the Gun of say 1½ cu. yd. of dry material per hour. A larger volume of air at higher pressure will greatly increase the capacity up to a maximum of about 4 cu. yd. per hour.

The working capacity of the Cement Gun depends upon many different factors. The experience of the crew, the kind of work to be done, and the method and thickness of the coating must be taken into consideration. The distance of delivery and the height of elevation, however, are of minor importance. As stated before, the capacity of the Cement Gun is up to 4 cu. yd. per hour, but if a thin coating is applied it is, of course, impossible to utilize more than a fraction of the Gun's capacity under actual working conditions.

In Fig. 4 the Cement Gun is shown in operation on a reservoir lining at Nashville, Tenn. The picture clearly shows the location of the Gun, the working crew, and the form of movable scaffold used on the job. The upper man on the scaffold is handling the nozzle and the two different lines for water and material uniting at the nozzle can be readily distinguished. The workman on the bottom is cleaning the surface by washing the same with a water jet of high pressure. The air compressor may be located wherever most convenient. It may be at practically any distance from the Gun. The connection is made by a flexible hose or a pipe line, and although there is a certain loss of air pressure due to friction in the line, in practical work this can easily be compensated for, and the loss is a negligible amount.

Before the cement coat can be applied, it is usually necessary to clean the surfaces and different methods must be used to meet the special requirements. While scum and dirt in reservoirs can often be washed off, it is at times necessary to use a sandblast for this purpose; especially is this true on steel work. Before old masonry, concrete, or brick work can be coated, it is frequently necessary to deepen the joints or even roughen the entire surface removing all loose and decayed particles from the structure. For such work the Cement Gun process is doubly advantageous for the reason that the Gun in itself is a most effective sandblasting machine. Both dry and wet sandblasting is done most advantageously with the Cement Gun while the powerful airblast can be utilized for removing loose dirt and dust. Air tools of all known varieties can be connected to the pressure lines and the flexible hose connections allow access to even the most concealed corners which could not be reached by any other method.

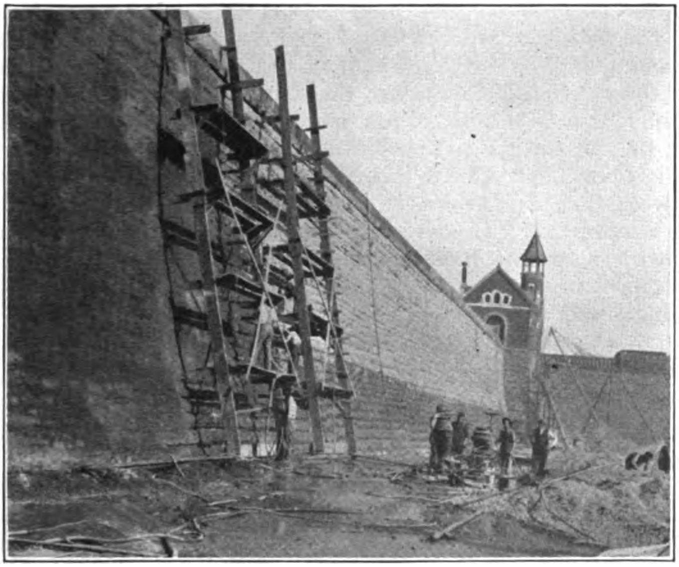


Fig. 4—Cement Gun in Operation at Nashville.

A good soft rubber-lined hose for this Gun will give over a month of continuous service if used with care. For longer transportation lines and in straight sections which are not moved frequently steel pipes may be used. For curved sections, however, rubber hose is imperative, as a curved steel pipe will be worn out after a few hours' work. The rubber lining of the nozzle will last from one to two weeks. Without this lining the brass nozzle end would be destroyed in a short time.

It is necessary that the hose be made of the most flexible pure soft rubber. Although such a hose is considerably higher in price than the ordinary varieties, it is by far the cheapest in operation owing to its lasting qualities.

For general information it may here be added that the weight of a Cement Gun is about 1100 lb. Its height to the top of the upper hopper is 54 in. The wheels are 36 in. high, and the extreme width is 37 in. The air line from compressor to Gun is usually 1¼ in. in diameter. The material hose is from 1 in. to 1½ in. inside diameter and the water hose to the nozzle is ½ in.

The air pressure is from 35 to 45 lb. per sq. in., and although an air compressor of about 100 cu. ft. capacity (free air) would suffice for all ordinary work, it is advisable to use a compressor of about 150 to 160 cu. ft. capacity. The cost of operating the larger compressor will be very little higher and is more than compensated for by the increased efficiency of the Cement Gun. A motor from 20 to 25 h. p. will be necessary for operating this compressor, and gas, steam, or electric power may be used as conditions suggest.

The working crew of the Gun usually consists of four to six men, which are a foreman, two or three material men at the Gun, and a nozzle man. This is all that is necessary for ordinary work. If, however, reinforcement is to be placed, or a special finish or surface preparation is required, the number of men must be correspondingly increased.

GUNITE.

As stated before, the product of the Cement Gun is called "Gunite" in order to distinguish it from ordinary cement stucco or plaster work, and for the reason that the material develops qualities which put it in a class all by itself.

Gunite is usually a cement mortar composed of about one part of Portland cement and three parts of coarse, sharp sand passing through a ⅜ in. screen. Although other compositions may be used and hydrated lime or any other ingredients may be added, it has been found in practice that the one-to-three cement and sand mixture is the most advantageous and efficient.

For ordinary stucco work on buildings, a one-to-four mixture is often sufficient, and even a still weaker mixture with a small percentage of hydrated lime added can be used if desired, or if utmost economy must be used on the work. For engineering work, however, the cement-sand mixture of one-to-three is mostly used without the addition of anything else.

To fully understand the advantages of Gunite over ordinary cement work, it is necessary that we follow the process of formation of the deposit as it occurs on the surface to be coated. Fig. 5 shows the nozzle in action, and the method of shooting is clearly demonstrated in this view. After the wall surfaces have been prepared for the Gunite coat by cleaning, or whatever other preparation such as tooling or the like was necessary, and after the reinforcement which is provided for the work has been placed, the stream of material is directed against the surface as shown.

The material leaves the nozzle with a velocity of about 300 ft. per second and as it strikes the hard surface the sand will rebound and fall down. Only the neat cement will first adhere until a coat thick enough to hold the sand has been formed. Then the rebound stops almost entirely and the coat is built up grain by grain until the required thickness has been attained. In this manner a film of neat cement is formed automatically between the old and the new work on every inch being covered, thus sealing every pore. Not only on the surface itself but also around every reinforcing bar or

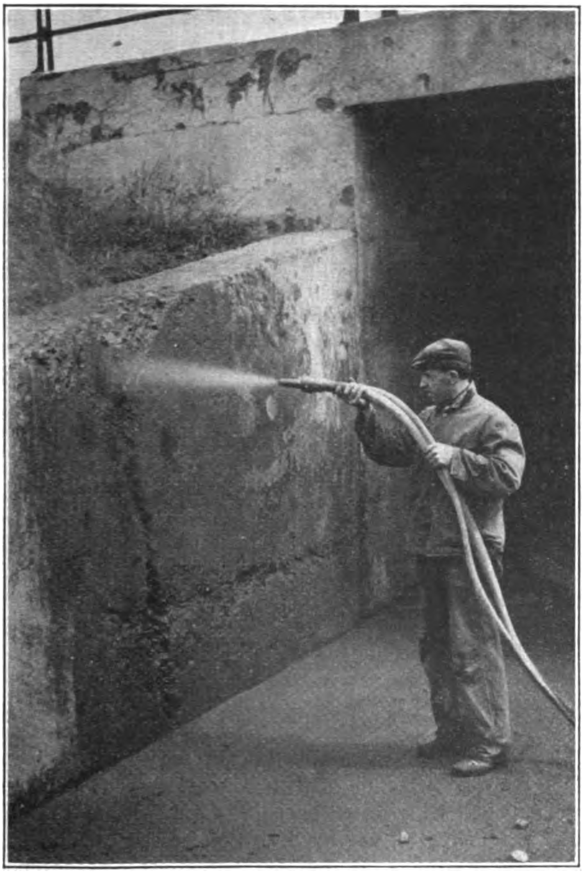


Fig. 5—Gun Nozzle in Operation.

wire the same process takes place and thereby a bond is secured which cannot be obtained in any other way. No matter what kind of a surface is being covered, steel or wood, stone, concrete or brick, the first film of neat cement is sure to be there regardless of the amount of sand added to the cement mixture.

This point is of great importance and every engineer or architect will fully appreciate its value. We all know how difficult it is to bond cement to old surfaces and that only an even coat of neat cement can give any assurance of success. In handwork, even in spite of most rigid specifications and inspection, it is practically impossible to get this bonding film applied in the proper manner and in the proper time. If applied at all it must of necessity be done ahead of the other work and be partially set before the actual coating is done, or even dry out and become worse than useless.

By the Cement Gun process this coat is formed automatically at the only moment when it is effective, and the most careless nozzleman could not omit it, even if he were paid a premium to do so. This bonding film of neat cement is characteristic of Gunite and is inseparable from its application.

As the "shooting" continues this forcing ahead of the neat cement by impact is continuously repeated, and every grain of sand which does not find a perfect bed or which is not immediately enveloped with cement will rebound and be forced out. Any pores remaining will be immediately filled by the following mass and all air and surplus moisture is forciby ejected.

The amount of water in the mass is regulated automatically under all temperatures and weather conditions. If not enough water is used the Gunite coat cannot adhere and all surplus moisture is expelled as demonstrated before. All the water regulation required by the nozzleman is to see that the Gunite coat sticks without running; the rest is taken care of by the Gun. The resulting Gunite coating must therefore be uniform throughout, of greatest possible density, and of 100% efficiency.

Another factor of great importance is that Gunite forms a perfect bond to the reinforcement which has been inserted in the coating, and at every place intimate contact between steel and concrete must exist. If, for instance, a thin cement coat is plastered by hand over a wire mesh or other reinforcement, the action of the float and trowel causes continuous jarring and vibrating of the steel within the cement mass, which is still further emphasized by the elasticity of the reinforcement and the suction under the trowel. In numerous places around the wires or bars, open spaces will be formed in which the wires lie without contact with the surrounding concrete. In Gunite this is impossible for the reason that the mass is built up around each individual piece of the reinforcement without the slightest vibration, and a loosening of the steel within the coating is impossible no matter how thin the same may be applied.

These facts have been confirmed by field and laboratory tests by Messrs. Westinghouse, Church, Kerr & Co., engineers, New York. The tests were made to compare the qualities of handwork with Gunite.

The final report of Westinghouse, Church, Kerr & Co., which very elaborately shows in figures, words, and photographs, all the different testing machines and methods employed, gives the results of these tests in the following sentences:

CONCLUSIONS.

> "In all of the tests made the product of the cement gun showed superior to good hand-made products of the same kind. The degree of superiority varied between wide limits.
>
> "In tensile strength the gun work excelled hand work in every case by amounts ranging from 20 to 260 per cent.
>
> "In compressive strength the excellence of the gun work was even more marked, ranging from 20 to 720 per cent better than hand work.
>
> "In the matter of surface permeability the gun work absorbed from 7-10 down to 1-20 as much water per hour, per unit of area as the similar hand-made surfaces.
>
> "As regards absorption of water, the hand-made mortars took up from 1.4 to 5.3 times as much as the gun-made mortars.
>
> "The percentage of voids of the gun-made product ranged from 52 to 75 per cent to that of the hand-made product.
>
> "The adhesion of the gun-applied mortars was on an average 27 per cent better than that of the hand work."

In Table I the results of the tensile strength tests are given in detail. Various mixtures of cement and sand were employed and to some of these mixtures lime to the amount of 15% and 25% of the weight of the cement was added, as shown in columns Nos. 2 and 3. The description of the different kinds of sand used is given in column No. 4, while the results occupy the last columns of the table.

Attention is called to columns 7 and 10 of this table, which show that Gunite is from 1½ to 2½ times as strong as hand made concrete of the same materials.

In Table II the results of compressive strength tests are tabulated. The same mixtures of cement, lime, and sand were used. The mixtures were applied by hand and by the Cement Gun to surfaces to the thickness of 2 in. Then 2 in. cubes were cut from these mortars by means of a metal cutter or die. The figures in the table are self explanatory. Attention is called to the last column, which shows the decided superiority of Gunite. The test pieces were 28 days old when the tests were made.

In Table III the results of the permeability tests are given. As most of the Gunite work is done for water and weather proofing purposes, for protection of steel structures, lining of water reservoirs, etc., this table is very important.

The same mixtures were used for these tests as given in the preceding pages. Concrete slabs 1 in. thick were prepared by plastering over a wire mesh. The slabs were 12 in. square and finished off on top as they would be in best practice. For the tests the specimens were coated with a ring of osokerite, and a round iron cap filled with water was clamped over the uncovered surfaces and tightened with rubber rings. A graduated glass tube to measure the amount of absorption was sealed into the iron cap. The rate

RESULTS OF TENSILE STRENGTH TESTS.

Mix No.	Proportion Cement to Sand	Lb. Lime added per bag of Cement.	Kind of Sand.	Age 7 days			Age 28 days		
				Hand Applied	Gun Applied.	Ration Gun to hand applied.	Hand Applied.	Gun Applied.	Ratio Gun to hand applied.
1	1 to 3	none	Cow Bay under 1-8 inch	187	359	1.92	254	441	1.74
2	1 to 3	15	do	231	377	1.63	255	390	1.53
3	1 to 3	25	do	230	323	1.41	232	351	1.51
4	1 to 4	none	do	140	268	1.92	196	353	1.80
5	1 to 4	15	do	157	293	1.86	180	337	1.87
6	1 to 4	25	do	131	345	2.64	175	355	2.03
7	1 to 3	none	under 1-16 in.	214	325	1.52	293	377	1.30
8	1 to 4	none	do	169	193	1.14	228	266	1.20
9	1 to 3	none	Std. Ottawa	214	463	2.20	290	661	2.30
10	1 to 4	none	do	164	346	2.10	222	601	2.70
11	1 to 5	none	do	108	530	4.90	148	540	3.60
12	1 to 3	none	Fine Beach Sand	70	206	2.94	94	234	2.50
13	1 to 4	none	do	67	183	2.73	93	232	2.50
14	1 to 5	none	do	71	113	1.59	89	179	2.00
15	1 to 4	25	do	108	200	1.85	124	215	1.70
16	1 to 7	none	do	22	83	3.80	40	101	2.50
17	1 to 9	none	do	17	73	4.30	26	92	3.50

Table I.

of absorption of the surface is given in cubic centimeters per hour on 0.02 square meters of surface, both for the hand and Gun applied mortars at the age of one month.

RESULTS OF COMPRESSIVE STRENGTH TESTS.

Mix No.	Proportion Cement to Sand	Lb. Lime added per bag of cement.	Kind of Sand	Hand applied Age	Gun applied 28 days	Ratio Gun to hand applied.
1	1 to 3	none	Cow Bay under 1-8 in.	2084	3530	1.7
2	1 to 3	15	do	1469	4031	2.8
3	1 to 3	25	do	1990	3000	1.5
4	1 to 4	none	do	1296	3122	2.4
5	1 to 4	15	do	1343	2487	1.9
6	1 to 4	25	do	1528	3205	2.1
7	1 to 3	none	Cow Bay under 1-16 in,	1695	4780	2.8
8	1 to 4	none	do	1008	2573	2.5
9	1 to 3	none	Std. Ottawa	2406	2936	1.2
10	1 to 4	none	do	1770	3459	2.0
11	1 to 5	none	do	1740	2949	1.7
12	1 to 3	none	Fine Beach Sand	1123	2547	2.3
13	1 to 4	none	do	663	2171	3.3
14	1 to 5	none	do	756	1270	1.7
15	1 to 4	25	do	1064	2571	2.4
16	1 to 7	none	do	362	709	2.0
17	1 to 9	none	do	99	811	8.2

Table II.

The last column shows the ratio of the surface permeability of Gunite to the hand product. In many cases of Gun work the absorption was so slight for the first hours of the test that it could not be accurately read on the scale of the apparatus. These tests were, therefore, continued for a number of hours, and to get the rate of absorption per hour the total absorption for the entire tests was averaged.

Table IV. shows the results of the absorption tests made to determine the total amount of water which in percentage of the weight of the specimen will be absorbed. For these tests the 2 in. cubes were made the same as used for the compression tests. At the age of one month the cubes were dried out, weighed, immersed in water for 24 hours, and then weighed again. The increase in

RESULTS OF PERMEABILITY TESTS

Mix No.	Proportion Cement to Sand.	Lb. Lime added per bag of cement.	Kind of Sand.	C. C.'s of Water absorbed per hour per .02 sq. Meter.		Ratio Gun to hand.
				Hand Made.	Gun Made.	
1	1 to 3	none	Cow Bay under 1-8 in.	3.0	.44	.15
2	1 to 3	15	do	3.2	.53	.17
3	1 to 3	25	do	6.9	.68	.10
4	1 to 4	none	do	11.7	.57	.05
5	1 to 4	15	do	14.4	2.0	.14
6	1 to 4	25	do	19.5	3.0	.15
7	1 to 3	none	Cow Bay under 1-16 in.	8.7	3.8	.45
8	1 to 4	none	do	7.5	3.2	.43
12	1 to 3	none	Fine Beach Sand	43.5	8.2	.19
13	1 to 4	none	do	21.9	11.2	.51
14	1 to 5	none	do	50.3	35.	.70
15	1 to 4	25	do	31.7	6.7	.21
16	1 to 7	none	do	250.	19.8	.08
17	1 to 9	none	do		31.	

Table III.

weight was taken as the relative absorption of the specimen. The results of these tests are summarized in this table. In every case Gunite showed considerably less absorption than the hand made materials.

RESULTS OF ABSORPTION TESTS.

Mix No.	Proportion Cement to Sand	Lb. Lime added per bag of Cement.	Kind of Sand	Per cent by wt. of water absorbed by hand made specimens.	Per cent by wt. of water absorbed by gun made specimens.	Ratio of hand to gun absorption
1	1 to 3	none	Cow Bay under 1-8 in.	5.1	3.67	1.4
2	1 to 3	15	do	5.9	2.72	2.2
3	1 to 3	25	do	5.7	3.10	1.8
4	1 to 4	none	do	6.2	3.25	1.9
5	1 to 4	15	do	6.7	4.03	1.7
6	1 to 4	25	do	6.0	3.15	1.9
7	1 to 3	none	Cow Bay under 1-16 in.	3.9	1.85	2.1
8	1 to 4	none	do	6.2	3.60	1.7
9	1 to 3	none	Std. Ottawa	3.5	.66	5.3
10	1 to 4	none	do	4.4	1.11	4.0
11	1 to 5	none	do	4.6	1.04	4.4
12	1 to 3	none	Fine Beach Sand	8.9	2.90	3.1
13	1 to 4	none	do	7.2	4.5	1.6
14	1 to 5	none	do	7.1	5.0	1.4
15	1 to 4	25	do	6.4	4.1	1.6
16	1 to 7	none	do	10.1	6.2	1.6
17	1 to 9	none	do	13.4	6.2	2.2

Table IV.

After the 2 in. cubes, which were tested at the age of one month for absorption, had attained the age of two months and had dried out thoroughly after the previous test, they were carefully weighed. They were then immersed in water for 48 hours, and boiled for 4 hours to expel any entrapped air which might be present; after cooling they were weighed wet, then weighed in water and the per cent of the volume of voids computed. Table V shows a summary of the average results of these tests for the several different mixtures.

RESULTS OF VOID TESTS.

Mix No.	Proportion Cement to Sand	Lb. Lime added per bag of cement.	Kind of Sand.	Per cent Voids Gun made specimens.	Per cent Voids Hand made specimens.	Ratio Gun to hand.
1	1 to 3	none	Cow Bay under 1-8 in.	12.7	19.2	.66
2	1 to 3	15	do	12.1	19.6	.62
3	1 to 3	25	do	9.0	16.0	.56
4	1 to 4	none	do	15.1	22.6	.67
5	1 to 4	15	do	14.3	19.1	.75
6	1 to 4	25	do	12.3	16.4	.75
7	1 to 3	none	under 1-16 in.	8.7	16.9	.52
8	1 to 4	none	do	10.2	19.8	.52
9	1 to 3	none	Std. Ottawa	5.3		
10	1 to 4	none	do	5.0		
11	1 to 5	none	do	4.6		
12	1 to 3	none	Fine Beach	14.4	24.0	.60
13	1 to 4	none	do	16.6		
14	1 to 5	none	do	20.5		
15	1 to 4	25	do	13.7		
15	1 to 4	25	do	13.7		
16	1 to 7	none	do	22.5		
17	1 to 9	none	do	24.1		

Table V.

Table VI gives the result of a series of adhesion tests made. As will be noted, a one-to-four mixture was used for the Gunite specimens, while mixture No. 1 (one-to-three) was used for hand work.

The tests were made by applying the mortar to the surface of the different materials and then after this coat (about ¾ in. thick) had slightly hardened, the specimen was placed in a form of about twice the length of the specimen, but of the same width and thickness. This mould was then filled with concrete after roughening the top surface of the mortar in order to get a good bond. Four reinforcing wires were inserted into the concrete for greater strength. The result was a composite specimen like a small beam, one-half the length of which was composed of brick, stone, or steel and the other end of concrete, but the joint between the two halves was in each case made either of Gunite or hand made plastering.

RESULTS OF ADHESION TESTS

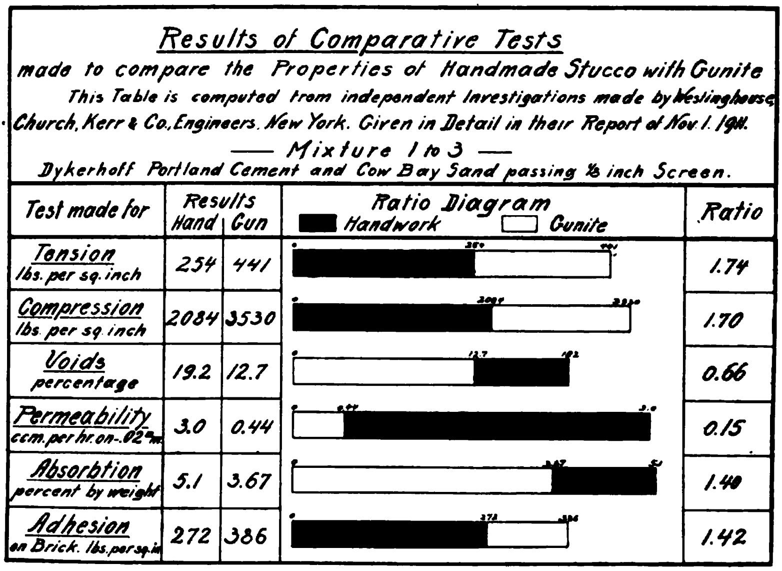
Mix	No.	Kind of Material	No.	Tests	Fibre Stress lb . per sq. inch		Ratio Gun to Hand
Gun	Hand		Gun	Hand	Gun	Hand	
4	1	Soft Brick	3	6	455	406	1.12
4	1	Medium Brick	2	8	358		
4	1	Hard Burned Brick	3	3	386	272	1.42
4	1	Finished Brick	4	4	411	406	1.01
4	1	Blue Stone Block	3	1	574	345	1.67
4	1	Sand Stone Block	2	2	573		
4	1	Granite Block	2	1	460		
4	1	Clean Iron "I" Beam	5	3	458	362	1.27
4	1	Rusted Iron "I" Beam	9	6	440		
Average of all tests on similar materials..................			30	24	465	365	1.27

Table VI.

In breaking these specimens they were supported on both ends on two round iron rods about 14 in. apart. Directly over the point of contact a round iron rod was laid crosswise on top and a receptacle was supported on this top rod and filled with weights until the specimen broke. From the measurements of the specimens, the distance between supports, and the breaking load, the tensile stress in the breaking point was computed.

Special attention is here called to the fact that in a number of cases the adhesion in the hand made specimens was so slight that they broke in handling before reaching the age of 28 days and they were, of course, not tested. Special care was required to produce good hand made specimens.

In order to show, in condensed form, the comparative values of results of these tests, I have made a ratio diagram for the one-to-three mixture as given in Table VII. In column 4 the black section indicates handwork and the light section Gunite. The values as given in the previous tables for this mixture are entered on the same scale, the zero point being the same in every instance.



Results of Comparative Tests
made to compare the Properties of Handmade Stucco with Gunite
This Table is computed from independent Investigations made by Westinghouse, Church, Kerr & Co., Engineers. New York. Given in Detail in their Report of Nov. 1. 1911.
— Mixture 1 to 3 —
Dykerhoff Portland Cement and Cow Bay Sand passing ⅛ inch Screen.

Test made for	Results Hand	Results Gun	Ratio Diagram ■ Handwork ☐ Gunite	Ratio
Tension lbs. per sq. inch	254	441		1.74
Compression lbs. per sq. inch	2084	3530		1.70
Voids percentage	19.2	12.7		0.66
Permeability ccm. per hr. on -.02	3.0	0.44		0.15
Absorbtion percent by weight	5.1	3.67		1.40
Adhesion on Brick. lbs. per sq. in	272	386		1.42

Table VII.

These tests, although they greatly favored the handwork, prove conclusively the superiority of Gunite. The hand made specimens were made with extreme care by expert union plasterers working under ideal conditions so far as material supply and everything else was concerned.

Consider for a moment how even the best hand stucco or plastering work is done in actual practice. Under most ideal working conditions it will be from 15 to 30 minutes before the mortar is taken from the mixer to the wall. By the Cement Gun process the material is deposited within a fraction of a second after the water is added.

The Cement Gun gives a perfect bond and forms a coating of a density which it is impossible to produce by any other known method.

COST OF GUNITE WORK.

There is a great difference in weight between hand made concrete and Gunite. Numerous tests have been made to ascertain correct values and it was found that the average weight of best hand made stucco after 28 days was 131.04 lb. per cu. ft., while the weight of Gunite made of the same mixture is 154.8 lb. Gunite is therefore 18.1% heavier, and of course requires correspondingly more material. In estimating Gunite work this difference must be considered and also the loss of sand caused by rebound as mentioned.

The amount of rebound varies, depending upon different factors, as, for instance, kind of surface to be covered, thickness of coating, kind of sand, kind and amount of reinforcement, weather conditions, etc. The loss will vary from 5% to 30%, and although in most cases the sand itself is recovered and used again, the loss must be compensated in the original mixture so as to get the desired results.

The amount of work which a Gun will accomplish in an hour and its cost depends on so many different factors that it is impossible to estimate without definite data.

As compared with handwork, we find that on large jobs the cost of a Gunite coating is much cheaper, while on small jobs, where the initial expenses are high or where the equipment must be shifted frequently, the cost may be somewhat higher.

In many cases, however, it will be practically impossible to make any comparison with handwork for the reason that most of the work done by the Cement Gun, especially on engineering structures, cannot be done by hand. Even in plain stucco work, where practically standard methods are employed, the Gun has a great advantage over other methods for the reason that a much lighter coating can be used. A ½ in. Gunite cover is fully as efficient as a 1 in. hand stucco, and the saving in material will often more than equalize the cost of installing the apparatus.

HANDLING OF CEMENT GUN EQUIPMENT.

The Cement Gun is not more complicated than any other machinery used on construction work. In order, however, to get the full benefit from the machine it is necessary that at least two experienced men be employed with every Gun. The first one acts as a foreman, and must know how to rig-up and manage the work for best results. He must be able to take good care of his machine, men, materials and supplies, and should also have had enough experience with carpentry work to build such light scaffolds, swings, and forms as may be required for the work. The second man must be a good nozzleman, have a steady hand and a keen eye, and be quick in his movements. A poor nozzleman will waste considerable time and material, and although he cannot spoil the quality of the work, he may do great damage to the appearance of the same. On his skill depends the cost of the finishing work and the amount of material used. This, of course, applies to most any line of work. Buying a set of carpenter tools does not make a carpenter, and getting a set of drawing instruments does not make a draftsman. It is the experience and skill behind the tools which make them valuable. It is therefore important, in placing orders, to see that the work is done by experienced operators.

THE WORKING FIELD OF THE CEMENT GUN.

Within the last few years several distinctly different lines of work have been developed by the Cement Gun, and some of the more important branches of this work will be illustrated and described.

A large number of brick, tile, stone, and wooden buildings have been coated with Gunite with great success.

In Figs. 6 and 7 two views of the First Baptist Church at Evanston, Illinois, are shown. This church had been covered previously with hand stucco which did not hold. Fig. 6 shows the appearance of the brick walls before the Gunite coating was applied.

In order to remove the last of the old stucco and prepare the wall for the Gunite coating, pneumatic bush hammers were used over the entire surface. The materials for the Gunite were limestone screenings and Portland cement mixed in the proportion of three-to-one. The thickness of the coating was about ¾ in. The limestone sills and trimmings of the church were also badly disintegrated and brought again to true lines, as shown in Fig. 7, which gives a partial view of the completed work. Numerous other brick buildings have been treated in a similar manner in all parts of the United States and elsewhere, among them being some very large warehouses at the New York docks.

Figure 8 illustrates how Gunite is applied to frame houses. Hundreds of such buildings have been successfully coated, and at a cost which allows most extensive use of the Cement Gun for this purpose. The house is at once made cooler in the hot summer days, and the cost of heating the house during the winter months is greatly reduced. The Gunite coat reduces the fire risk and, being practically indestructible, will prolong the life of the building.

On all work applied to wood the Gunite coat is reinforced with a light wire mesh which is nailed against the surface to be covered. The thickness of the coating is usually ¾ in. Any desired finish can be given, and frequently coloring matter is used in the last coat to good advantage.

All parts of the building which are not to be coated, such as windows, cornices, etc., must be protected with tar paper, cloth or the like for the reason that it is difficult to remove unavoidable cement splashes.

Figure 9 shows a large reinforced concrete power house with chimney, the surfaces of which have been covered with a thin Gunite coating to conceal the form marks and to produce a uniform finish for the entire structure. In this same view is a tall chimney 150 ft. high. The finish was applied with the Gun standing at the ground level and the material was shot to the top without any inconvenience. This illustrates the carrying power of the Cement Gun and the adaptability and advantage of the machine for work difficult to approach. Only a very thin coat is usually required to cover the form marks and the bond is perfect without

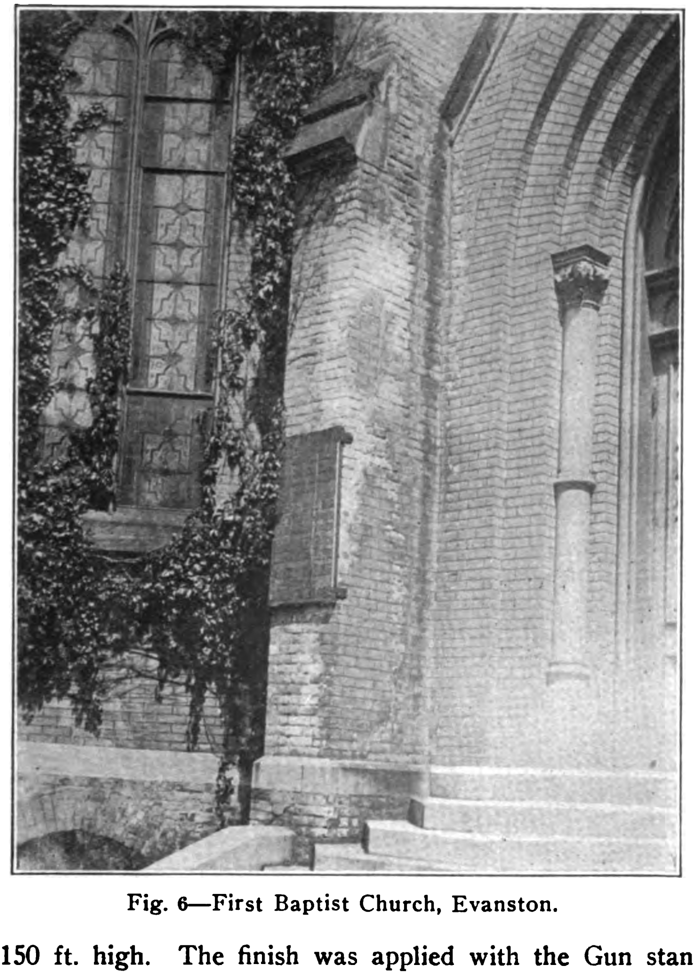


Fig. 6—First Baptist Church, Evanston.

the employment of any artificial means. The Gunite finish forms an integral part of the entire structure and at the same time waterproofs it effectively. It is conveniently applied to all surfaces as walls, floors, ceilings and roofs. For coating expanded metal and rib metal the Cement Gun provides an economical method. The cost of forms and scaffolds can be almost entirely eliminated on most of such work.

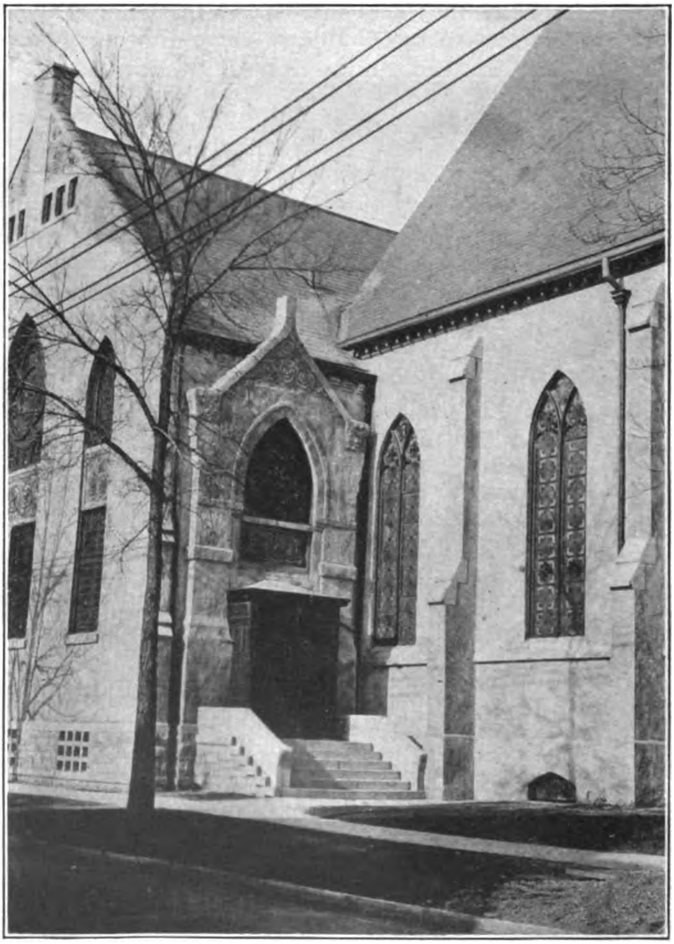


Fig. 7—First Baptist Church, Evanston.

The Cement Gun has been used for the construction of thin partition walls and hollow walls for buildings. For such work no forms are required except a light frame covered with building paper to hold the reinforcement in place and to act as a temporary backing. This framework is usually made of 2 in. by 4 in. uprights, spaced about 18 in. center to center. After the Gunite has set, the frame may be removed and another finishing coat applied to the back, or the frame can be left in place. Often both sides of the frame are covered alike and a cheap and strong hollow wall is the result. A number of residence buildings have been erected where practically all cement work was done in this manner with the Cement Gun at a saving of cost over other constructions which might have been employed.

Figures 10 and 11 show the Gun work done on the new warehouse for the Illinois Steel Warehouse Company at St. Paul, Minn. The building is a steel and concrete skeleton structure and all the curtain walls between the frame work have been built by Cement Guns. These curtain walls are 2 in. thick and reinforced with No. 6A triangular wire mesh. A light wooden form was used on the inside as backing and to hold the wire mesh in place. The convenience with which the work was done is illustrated in Fig. 10, which shows the workmen standing on the hanging scaffolds. Two Guns were in operation in order to finish the work in the shortest possible time to avoid the winter season. Fig. 11 shows a finished portion of the building.

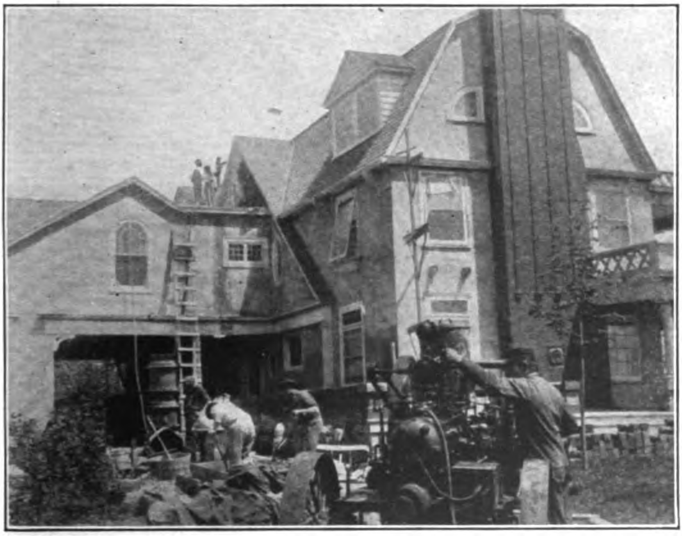


Fig. 8—Showing How Gunite Is Applied to Frame Houses.

Gunite has been used for the waterproofing of reservoirs, canals, aqueducts, bridges, basements, etc. The most important point in connection with such work is the fact that no ingredients or compounds are used which are foreign to concrete or which may gradually deteriorate. Gunite consists of cement and sand only and is waterproof on account of its characteristic density.

Figure 12 shows the Twin Peak Reservoir at San Francisco. One-half of it is filled with water, while the other half, being perfectly dry, was used as a temporary auditorium. This reservoir is 370 ft. long, 285 ft. wide, and 27 ft. deep, and when filled it holds 11,000,000 gallons. The partition wall is 1 ft. thick and is supported by buttresses placed 8 ft. apart on both sides. When the reservoir was first filled, it was found that in spite of all pre-

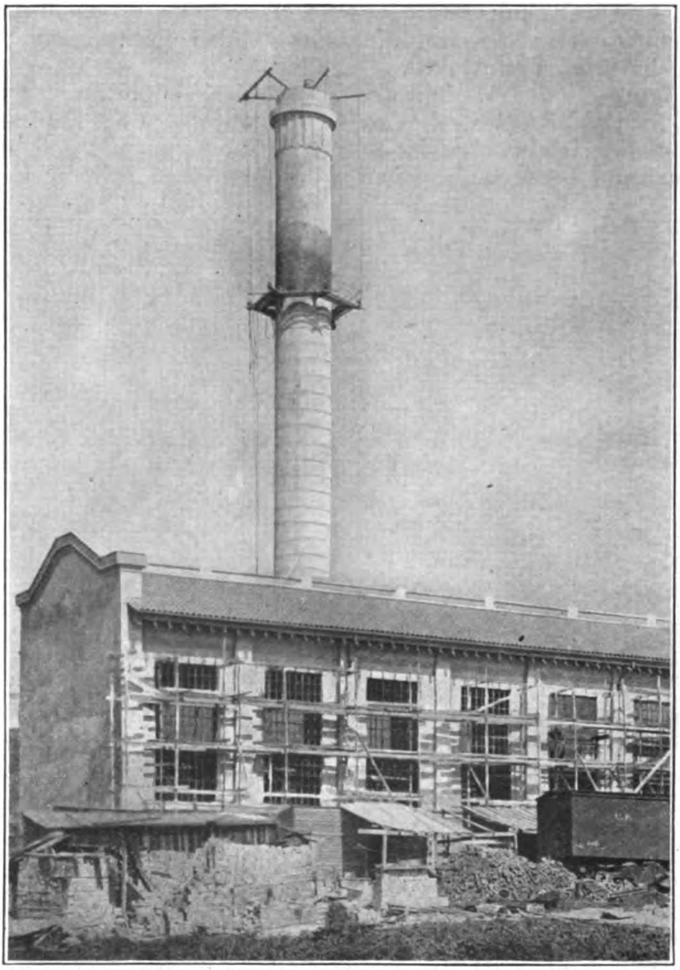


Fig. 9—Reinforced Concrete Power House With Gunite Coating.

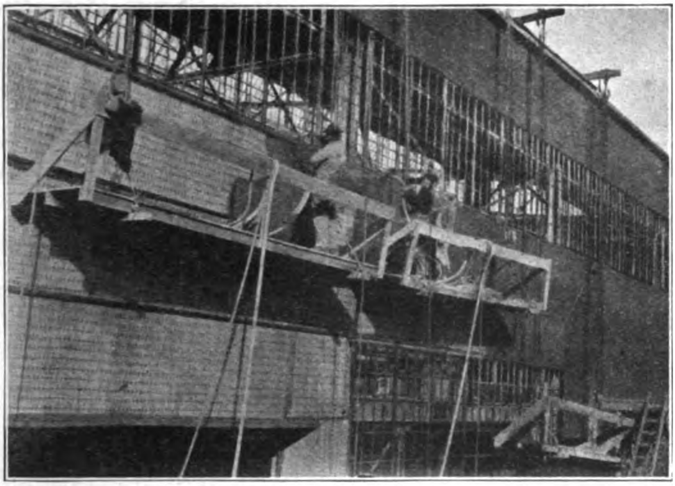


Fig. 10—Showing Gun Work on New Warehouse for Illinois Steel Warehouse Co., St. Paul.

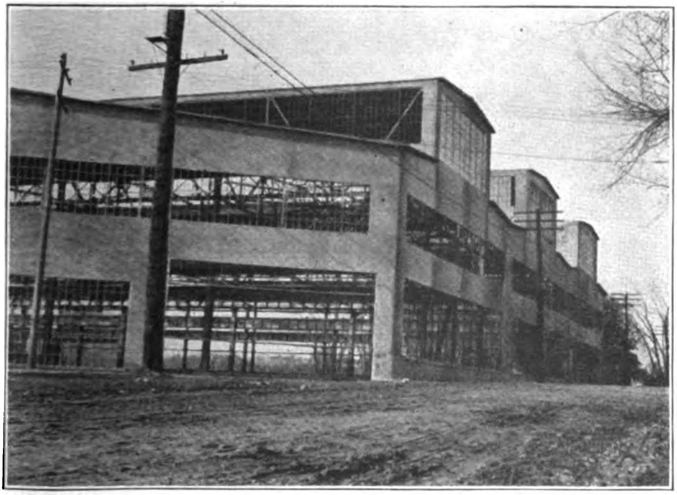


Fig. 11—Another View of St. Paul Warehouse.

cautions taken, considerable water found its way through the wall, and therefore it was finally decided to use the Cement Gun for the purpose of waterproofing it. A coat of Gunite only ¼ in. thick at the top and increasing to ½ in. at the bottom was applied on both sides of the partition wall and the buttresses. Immediately after the Gun work was finished one-half of the reservoir was filled, with the result as shown.

Another large reservoir waterproofed with Gunite is the water reservoir of the city of Nashville, Tenn. The work is shown in Fig. 4. The stone walls are 36 ft. high. The reservoir is round, 463 ft. in diameter, and with a dividing wall as shown. This reservoir broke on account of seepage and had to be partially rebuilt. The inside and partition were waterproofed with Gunite. This was also applied over the surface averaging 1½ in. in thickness, following the contours of the rough stone wall. The bottom was sealed with a concrete floor.

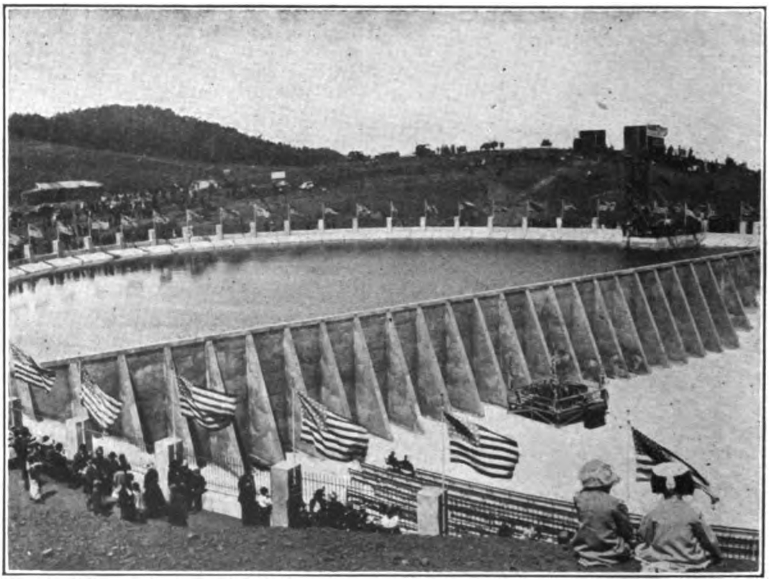


Fig. 12—Twin Peak Reservoir at San Francisco.

Another field which the Cement Gun has entered is the repair of such stone, brick, steel, and concrete structures as have developed weakness and have deteriorated under the influence of loads, water, and atmospheric conditions. In Fig. 5 we have already seen how this work is done.

A remarkable example of repair work is that of the concrete piers of the Dover Street Bridge in Boston. Fig. 13 shows the condition of the piers after the worst rubbish had been cleared away and also very plainly shows the line to which the tide rises at regular intervals. During high tide the piers are almost completely under water and therefore ordinary repair work would have required the construction of a temporary cofferdam around the pier. It was then decided to use the Cement Gun for this work and Fig. 14 shows the successful completion of the work.

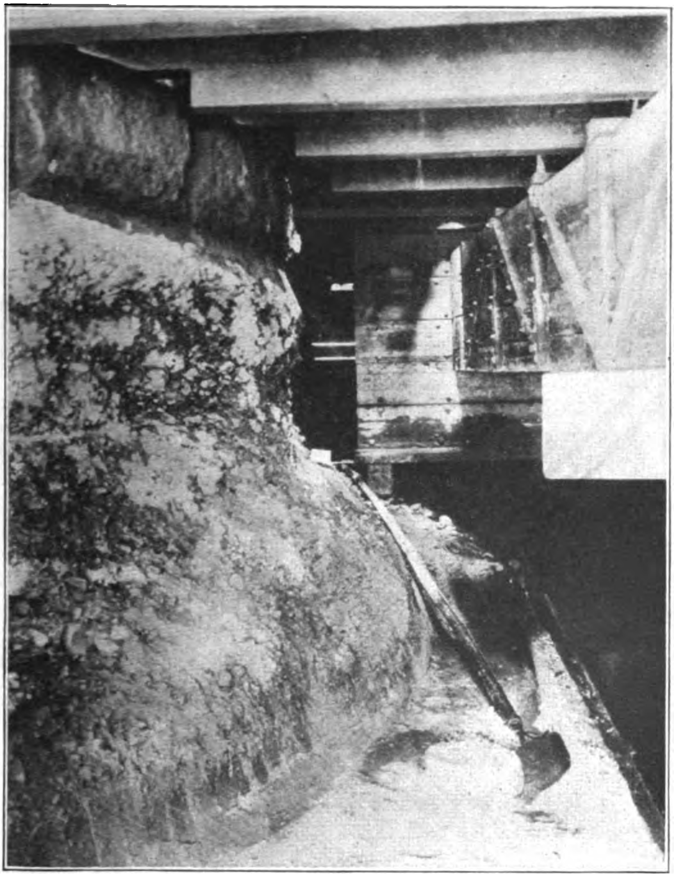


Fig. 13—Concrete Piers, Dover Street Bridge, Boston.

All the work was done between tides, without any forms or other equipment. Fig. 14 shows very plainly the tidemarks on the new work. The Cement Gun deposited the material with such force, and compacted the same so densely, that even the rising tide could do no harm to the new Gunite work.

The same conditions had to be met on the repair work of the sea wall at Lynn, Mass., and on numerous other jobs all along the Atlantic and Pacific Coasts.

In Fig. 15 the Cement Gun is shown on tunnel repair work. The brick lining in the single track tunnel on the Chicago, Milwaukee & St. Paul R. R. near Tunnel City, Wis., was badly worn by the locomotive blasts. The mortar filling on the roof had been so damaged and the lower course of bricks so worn away that repair work became necessary. The tunnel is 1,330 ft. long. There being an average of 32 trains per day at this point, and all tonnage freight being operated with pushers, this allows very short working time between trains and therefore the repair of the tunnel was a difficult problem. The method finally adopted was to place a

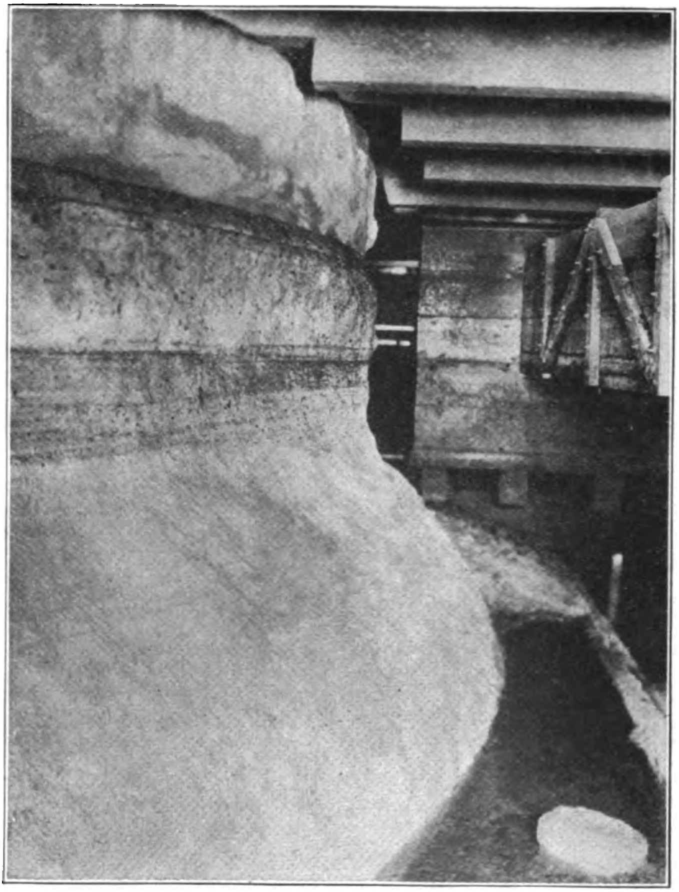


Fig. 14—Same View as Fig. 13, After Using the Cement Gun.

Gunite coat over a strip 8 ft. wide on the under side of the center of the arch and the results have been satisfactory.

Before placing the Gunite the surface was cleaned with a sand blast. No. 4 triangular mesh reinforcement was used in a single layer and placed in 8 ft. lengths at right angles to the tunnel axis. The Gunite was applied in two to five coats, depending upon the thickness necessary. The concrete never extended into the old lining for a distance greater than the thickness of one brick and projected 2 in. beyond the old face of the lining. This made the total thickness vary from 4 to 6 in.

In planning for this work it was thought that some form of shield would be necessary to protect the fresh concrete from locomotive blasts until it had thoroughly set, and a movable shield to be supported from the roof was accordingly built and used at the beginning of the work. It was soon found, however, that the cement placed by the Gun was so hard immediately after placing that the locomotive blasts had no effect upon it and the use of the shield was discontinued.

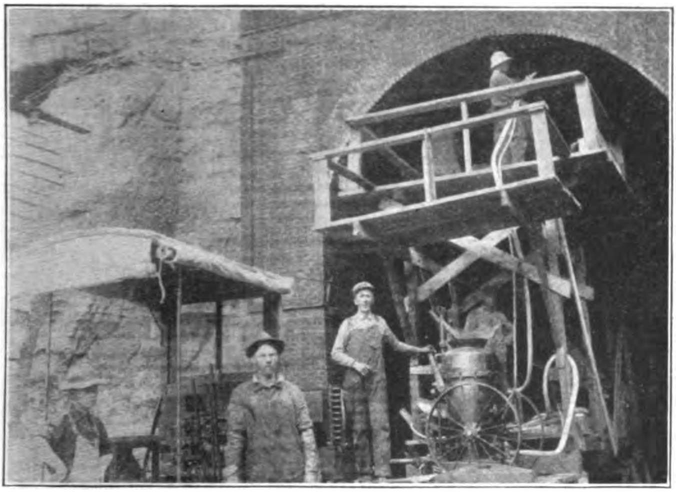


Fig. 15—Use of Cement Gun on Tunnel Repair Work.

The portable compressor plant was located at the east portal. a 2 in. pipe was carried through the tunnel with connections at frequent intervals, and the Cement Gun and mixing board were carried on staging supported by two standard gauge cars coupled together. A Fairbanks-Morse gasoline locomotive was used to push the equipment in and out of the tunnel. It was necessary to remove the entire outfit to a siding at the east portal for every train movement. The work was carried on for about two months, the progress being about 210 ft. a week.

Another interesting piece of railroad work is shown in Fig. 16. The picture shows a portion of the deep rock cut on the Erie R. R. just outside of Jersey City known as the Bergen Hill Cut. The work of the Cement Gun consisted in cleaning the fissures between the different layers of the rock and then filling them with cement mortar to eliminate the danger from falling rocks and to retard disintegration. The hanging platforms used for this work and the simplicity of the whole arrangement are shown.

Of an entirely different nature is the work shown in Figs. 17 and 18, which illustrate a coal bunker about 25 ft. wide, 20 ft. deep, and 150 ft. long. This coal bunker, which is built at the Haskell-Barker Car Company's works at Michigan City, Ind., was lined with Gunite in order to protect the bunker against abrasion and the action of the sulphur in the coal, which will weaken the steel work in a short time. The lining is 2½ in. thick, reinforced with No. 7A American Steel & Wire Company's triangular mesh. This mesh is fastened to angle irons riveted to the steel work for that purpose. The work has proven successful and although no provisions whatever were made for expansion joints, not a crack appeared in the work.

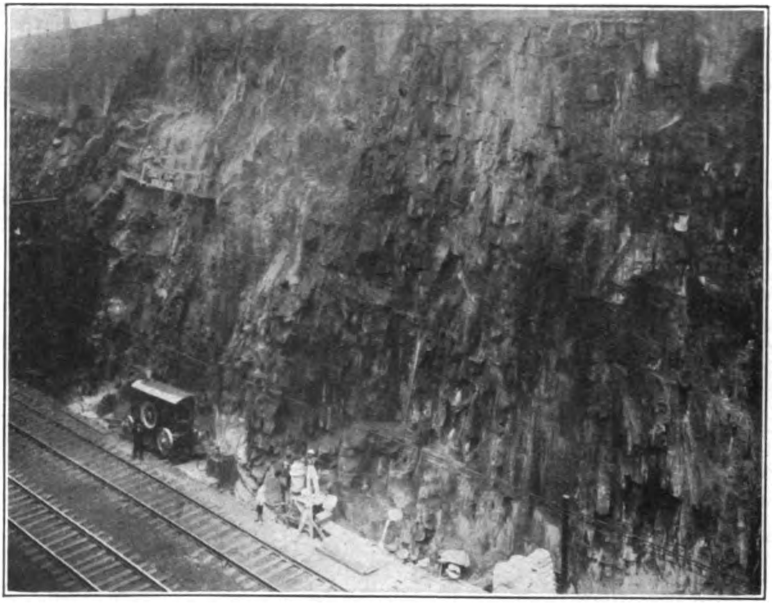
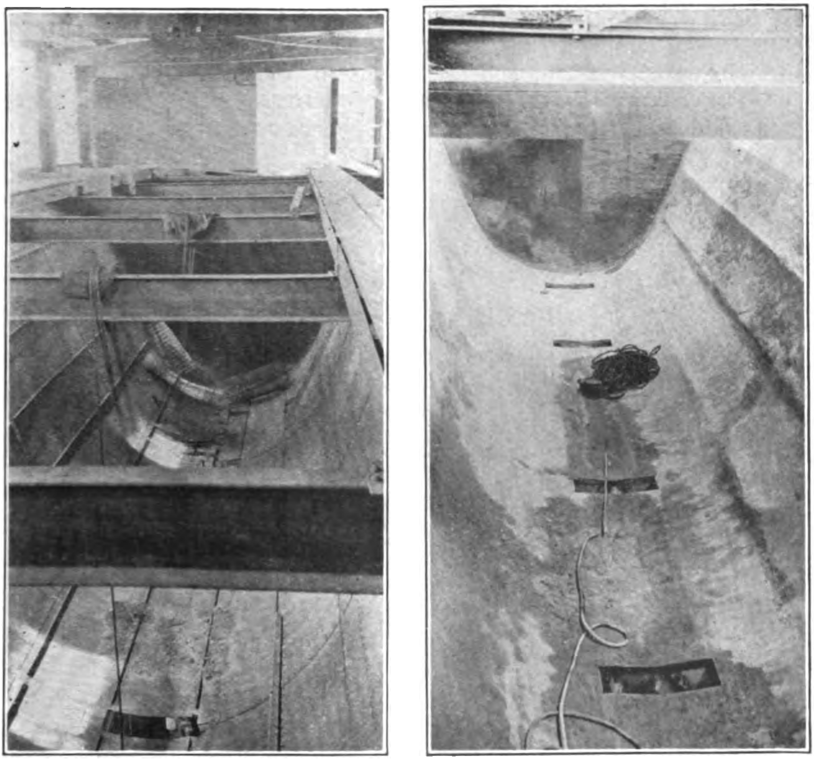


Fig. 16—Deep Rock Cut on Erie R. R.

There is a large field for this class of work, as practically no protection is given the steel work in such bunkers at the present time. The saving in cost for repair and renewal is soon equal to many times the cost of the Gunite lining.

Numerous old and new steel bridges and viaducts have been coated with Gunite to protect the steel work against rust and the corrosive action of the gases emitted by locomotives, etc. The Gunite covering also deadens the noise of traffic over these structures and greatly improves their appearance.



Figs. 17-18—Coal Bunker at Michigan City, Ind., Lined With Gunite.

For old bridges, where the corrosion has gone so far as to practically demand renewal, the Cement Gun suggests the reconstruction at a saving in cost by a new process. The steel work after having been cleaned and freed from all rust, scale, and loose paint, is wrapped with wire mesh. To make up for lost steel area and to provide additional strength, reinforcing bars may be placed as in ordinary practice and then the whole structure coated with Gunite from 2 to 6 in. in thickness as conditions may demand. In this manner the old structure can be saved, practically a new bridge being formed without interruption of service and without any great expense for forms, scaffolding or the like. The reconstructed bridge will then be a permanent structure and of superior strength and appearance to the old one.

Figure 19 shows the new South High Street Viaduct at Columbus, Ohio. The length is about 350 ft. and the width is 70 ft. The steel work of the entire structure, including columns and braces, has been coated with Gunite about 2 in. thick and the appearance of the work after completion is illustrated. In Fig. 20 we have a close view of the nozzle at work on this job. The air compressor and Gun are standing on top of the steel work, and the wire reinforcement and the process of coating can be seen.

For coating the steel in our modern skyscrapers and other steel skeleton structures Gunite has been used with success. In Fig. 21 we have a close view of some of the steel work of the new 56-story Woolworth Building in New York. In this giant of skyscrapers practically all of the steel work has been protected by covering with Gunite.

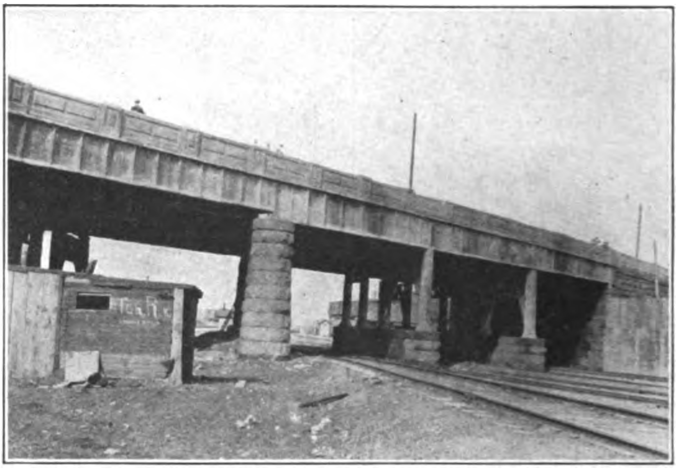


Fig. 19—New South High Street Viaduct, Columbus, Ohio.

Use for the Cement Gun was found in the new Grand Central Terminal Station in New York, where over 3,800,000 sq. ft. of steel work was covered as shown in Fig. 22.

Extensive waterproofing work has also been done at the Chicago Stockyards and elsewhere and this branch of the work is rapidly expanding.

For fireproofing purposes, the Cement Gun is valuable. In Fig. 23 we see a large corrugated metal partition wall at the Northwestern Station of the Commonwealth Edison Company, Chicago. This wall is 85 ft. high, 170 ft. long, and was built of corrugated metal and asbestos on steel frame and board sheathing. The Board of Fire Underwriters condemned the wall as not being sufficiently fireproof and the Cement Gun was used with success to coat the wall with Gunite. A light 1½ in. mesh poultry netting was stretched over the metal and a 1 in. coating of Gunite applied thereon.

In the same manner old corrugated iron sheds, warehouses, and factory buildings can be transformed into permanent structures even if already badly rusted. The cost for this work is comparatively low and can be carried on in most cases without interfering with the service of the buildings.

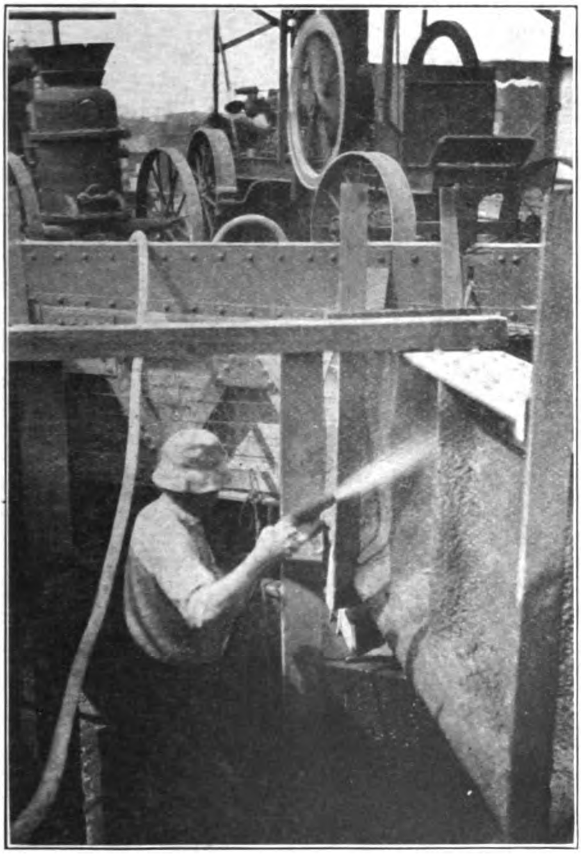


Fig. 20—Nozzle at Work on Columbus Viaduct.

In Fig. 24 a difficult Cement Gun job is illustrated. The work consisted of repairing the spillway of the Public Service Corpora-

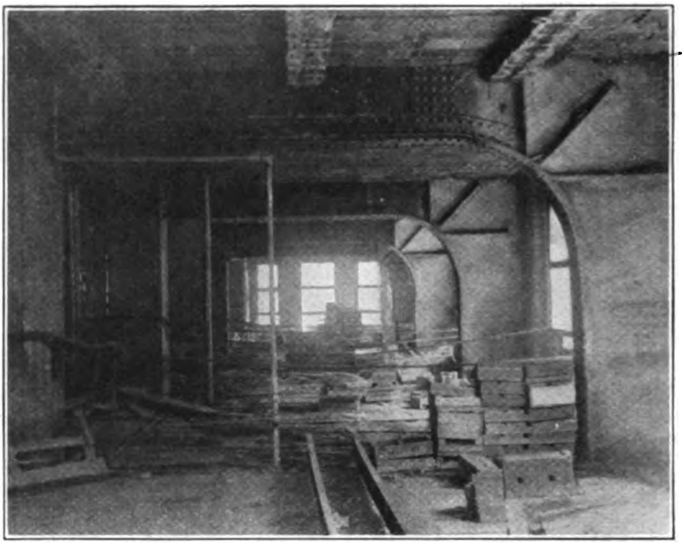


Fig. 21—Steel Work, Woolworth Building, New York.

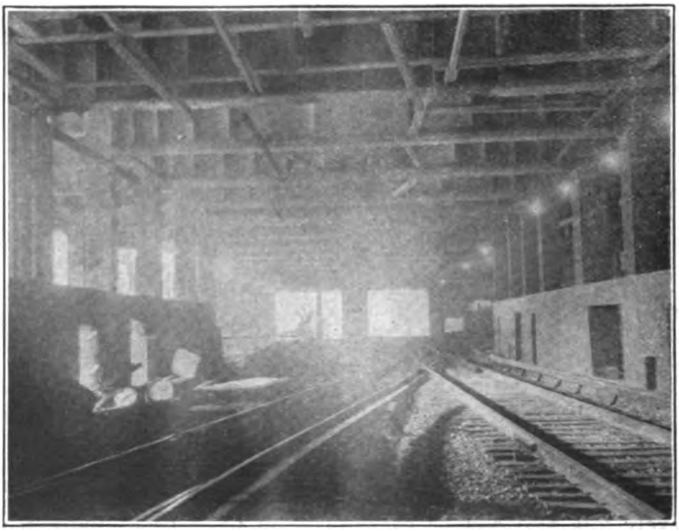


Fig. 22—Grand Central Terminal Station, New York.

tion at Joliet, Ill. The spillway is 90 ft. wide and has a swift current. The material had to be shot across the channel, the Gun being located at the other side. Practically all the work had to be done from scows. The work consisted of placing a 6 in. curtain wall over the badly deteriorated face of the foundation wall of the station. This curtain wall is 650 ft. long, 12 ft. high, and is reinforced with ½ in. steel rods and American Steel & Wire Company's triangular mesh No. 7. The greatest difficulty was encountered by the inflow of water due to leaky gates from the station. Numerous drains had to be placed in the work to overcome this trouble. The curtain wall encases and protects the intake pipe for the railroad water supply station which carries water at a pressure of about 90 lb. per sq. in.

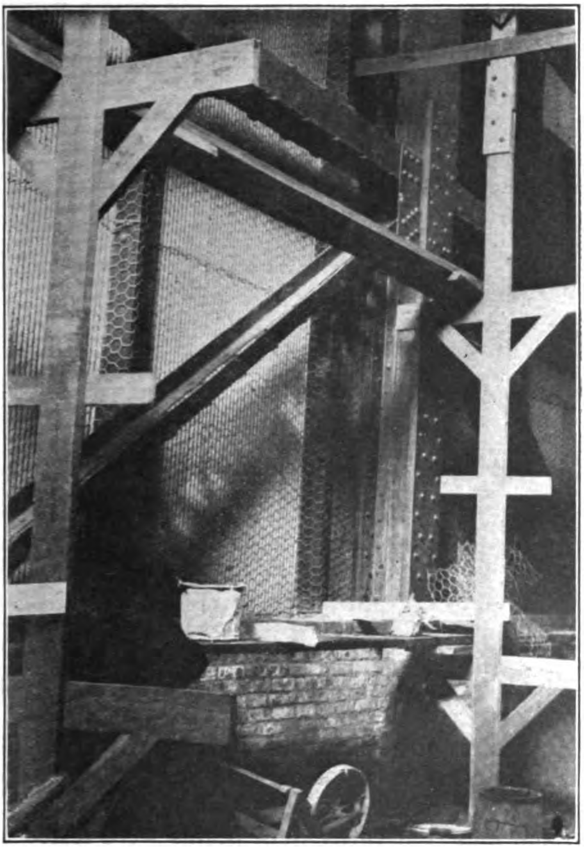


Fig. 23—Metal Partition Wall, Northwest Station, Commonwealth Edison Co.

From these descriptions and illustrations the value of the Cement Gun for engineering and architectural work will be appreciated. At a later time I hope to be able to give more explicit information along some new lines now in the stage of development. I refer especially to the use of the Cement Gun for the manufacture of concrete units for building construction, as, for instance, floor and roof slabs, curtain wall sections, hollow floors, beams and columns, pipes, fences, etc. I am sure that the results will practically open a new branch of reinforced concrete construction. For example, two H-shaped Gunite beams, 12 in. high and 12 in. wide, were recently made. The web and flanges are 1 in. thick, reinforced with single layers of American Steel & Wire Company's No. 7A, triangular mesh. The longest span between supports was 12 ft. 6 in. and these extremely light beams were tested up to 500 lb. of live load per square foot of floor space. At this load the final result was the toppling over of the load, beam, etc., which of course fractured the beams. The beams and tests were made in a rather crude way and therefore the results are not conclusive; but the results indicated the enormous strength of pre-molded Gunite members as compared with ordinary concrete and also the resulting economies. Especially remarkable is the ease with which they can be molded with the Cement Gun even if of complicated design.

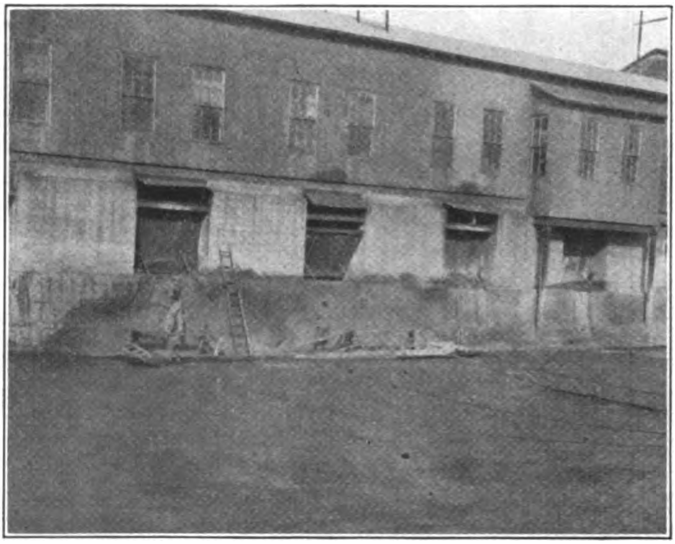


Fig. 24—Repairing Spillway, Public Service Corporation, Joliet, Ill.

DISCUSSION.

J. H. Prior, M. W. S. E. (Chairman): The author has stated that the velocity of the sand and material from the gun was about 300 ft. per second. I would like to know what is the velocity of the air.

Mr. Weber: The velocity of the air is, as near as I can remember, about 380 ft. per second. The air, of course, must move more rapidly than the material itself.

Mr. Prior: The velocity of a 32-caliber bullet is only about 500 ft. per second.

Mr. Weber: I might mention that we have, every minute, about 150 ft. of free air discharging through a ¾ in. nozzle, and it is very easy to figure the absolute velocity.

Mr. Prior: I notice the author spoke of the material being deposited at 100% efficiency. If some improvements are made in the gun—as there surely will be in the next ten years—I am wondering what its efficiency will be then.

Mr. Weber: Any improvements which will be made in the cement gun in the future will be along the lines of greater facility in handling it. These improvements will mean larger guns with greater capacity and an attempt to reduce the cost of operation by finding some way to get along with less air than is now being used. We all appreciate that considerably more power is used than should be necessary according to the best theories. There is at present a great loss and waste in this respect, which we shall probably overcome with improvements. To get greater efficiency out of the material will of course be impossible.

Mr. Prior: The mere patching of concrete work has been a thorn in the side of everybody responsible for its maintenance for a generation. If the cement gun offers a way out, which I think it does, that alone is a tremendous achievement.

There are many here tonight who are familiar, not with the cement gun, perhaps, but with many of the problems to which it can be applied. We shall be glad to hear from them.

R. S. Draper, ASSOC. W. S. E.: Has Gunite ever been applied to wall surfaces to waterproof them against a head of water on the other side?

Mr. Weber: A good deal of such work has been done in the new Sears-Roebuck plant here in Chicago. On account of the great density of the material, it is especially suitable for this purpose. Of course, we have to insert weeper pipes in the wall to temporarily drain off the water. After the coating has set around these pipes, they can be stopped up. This work has been done very successfully.

Mr. Draper: How does Gunite resist sea water as compared with ordinary concrete?

Mr. Weber: On account of the density of the material, the action of the alkali in the water is at least greatly reduced. The action of alkali on cement can take place only if this salt enters the mass and causes a chemical change in the concrete itself; where this cannot take place, naturally there cannot be any destructive action.

E. B. Wilson, M. W. S. E.: In the case of the Woolworth building in New York, what did they do to remove the paint that might be on the surface of the steel?

Mr. Weber: The cement gun is also a very effective sand blast. We use it for sand-blasting purposes in a great many instances by using sharp sand only and directing the material against the wall at a cutting angle. Paint, rust, and scale are thus easily removed. As a rule, after we have sand-blasted a surface we shut off the sand and go over it again with an air-blast to blow away the last portion of any loose material which may have lodged in the corners.

Mr. Wilson: Is it advisable to remove the paint from the surface of the steel before applying the Gunite?

Mr. Weber: As a rule, this is done only on surfaces where the paint is affected. But in cases where the steel-work has only the factory coat, if this coat is in good condition it may not be necessary to remove it. If the paint shows defects, it is advisable to remove it before applying the Gunite.

Mr. Wilson: I have seen several pictures of the Woolworth building, where paint was being put on the steel, and I was wondering whether they had purposely painted the steel prior to putting on the Gunite coating.

Mr. Weber: I am not familiar with the details of that work, but I believe I am correct in assuming that the Gunite covering was decided on after the factory painting had taken place, and it was not considered necessary to remove it. If it has been decided in the first place to use Gunite over steel work, painting is not necessary. In fact, it will be better for many reasons to leave the steel unpainted, because Gunite adheres better to unpainted steel. There is a chemical surface action between cement and steel which cannot take place if a coat of paint interferes.

Mr. Wilson: Do the cement gun people recommend, or is there any decided tendency to use, coloring matter on coating old brick-work, for instance?

Mr. Weber: That is entirely a matter of taste. It is a very simple matter to apply a colored coat on such structures, and if anybody desires, for instance, to match up the work with brick buildings, etc., he can practically match any shade he may desire. Of course, coloring is a little more expensive than ordinary work, but it has been done successfully in many instances.

Mr. Wilson: I have in mind the case of the church in Evanston, where there was a variety of coloring on the face of the building shortly after it was coated. Could not that effect have been overcome if coloring matter had been used? Some of the discoloring has now disappeared, or at least it has been very materially reduced.

Mr. Weber: The materials used on the Evanston church job were limestone screenings and cement; it seems as if limestone screenings and any other stone screenings have a greater tendency to discolor than ordinary sand. On a sand coating we seldom have any trouble from spotty coloring.

Mr. Wilson: That is probably on account of the difference in the mix and the greater amount of fine dust in the crushed stone.

Mr. Weber: That may be true. As you know, screenings never run so uniformly as, for instance, torpedo sand. We have always, no matter how carefully we choose the material, an accumulation of fine and coarser material in the same batch. It cannot be exactly regulated.

Mr. Prior: Mr. Boynton has had considerable experience in all these lines and we should like to hear from him.

C. W. Boynton, M. W. S. E.: I think a wrong impression might be had with reference to the coating of steel in the Woolworth building. I understand that the coating was put on as a fireproofing and was not necessarily intended to adhere to the steel, but was supported by a metal fabric cage. Possibly this explains why the paint was not cut off. Where the Gunite is applied directly to a steel member and is held in place by adhesion, it is necessary, I believe, to clean the steel. We certainly would not want a film of paint intervening between the Gunite and the steel.

In reference to the waterproofing of a wall against water pressure with the head temporarily removed, this has been done very successfully. The material is so very dense and the adhesion is so perfect that it becomes a part of the original structure. I have seen tests made where the Gunite was placed on stone, hard-burned brick, or concrete, and then subjected to a test which would tend to develop the strength of the bond, and in every instance the bond has developed as great strength as other parts of the mass.

I am inclined to question whether or not the gun people have reached 100% efficiency; but whether they have or not is not really material at this time. We do know that the gun has great possibilities for certain lines of work, and it seems to me the principal thing is the work that it has been doing in repairing the poor work of someone else. We all regret that there is so much poor concrete work and we are equally glad to know that there is some way by which it can be repaired. I wish to ask what it would cost, ordinarily, to place an inch coat, say, on a horizontal surface and also on a vertical surface. On a vertical surface, metal fabric would be required, while on the horizontal surface it would not be needed.

Mr. Weber: The question which the last speaker asks is a very hard one to answer directly, for the reason that so much depends upon the amount of work to be done in one place. We use a pretty heavy equipment, and to carry this from place to place means expense. That is one portion of the cost. The material requirements for the Gunite work are from 20% to 25% more than handwork, owing to the loss by rebound and the additional density in the material. Therefore, it is very difficult to set a price and make this price stand out as something to go by. We have done work of this kind, 1 in. thick, as low as 70 to 80 cents a yard, while other jobs have run up to $1.50. That, of course, includes the reinforcement which has been used. Overhead work is a little more expensive than work on the side walls or work on the floor. If we figure on a job where different work is done in any quantity, it is all averaged and the average price taken. A 1 in. coating costs, on the average, about $1.00 per square yard. This average price may be used for rough estimating purposes. For actual practice, of course, the work has to be figured for every job according to the actual conditions.

Mr. Prior: The author has given us a new use for cement. We might say he has given us a new use for compressed air.

C. W. Melcher, ASSOC. W. S. E.: What thickness of coating is necessary for steel protection? I refer to exposed work.

Mr. Weber: As to exposed steel work,—for bridges, etc.—I have before me the Bulletin of the American Railway Engineering Association for January, 1914, in which a complete report is made by the Committee on Iron and Steel Structures for such work. I see from the drawings furnished by Mr. Tebbetts, bridge engineer of the Kansas Terminal Railway, that they apply 3 in. of material on their bridge work where it is exposed to locomotive blasts. On a viaduct at Little Rock a 3 in. coating was also applied. I believe that such a heavy coat is not necessary, however; it seems to be the present-day practice to apply 3 in. on such bridges. If steel work is coated, on exposed surfaces in buildings where reinforcement is used 1½ in. to 2 in. should be sufficient; less than 1 in. should not be used in order to have some "body" in the mass.

Mr. Melcher: What I referred to particularly was the prevention of rust on reinforcing.

Mr. Weber: To get rust prevention without reinforcing, a ½-in. coat is all that is required, but there is always a certain amount of vibration, and there being no "body" in a thin coating, it would be more apt to loosen than if a coat with more stiffness in itself were used, with proper reinforcement. I believe 1½ in. is about the least we should apply to such steel work.

D. P. Gaillard: Would it be possible to use Gunite on the old

Field Museum building in Jackson Park to restore it, and if so could it be done at a reasonable cost?

Mr. Weber: There is absolutely no question as to the feasibility of using Gunite for the purpose mentioned, and at a cost less than that of any other process. As a matter of fact, the first cement gun was operated on the Field Museum. A light coat of gypsum stucco only was then applied, and at a later time the question was taken up of applying a permanent coating of Gunite and transforming the structure into a permanent one. If it is ever decided to leave the Museum on its present site, we shall certainly "get busy" on the work of restoring it.

O. F. Dalstrom, M. W. S. E.: The author has referred to the material being put on in coats. I would like to know if it is put on in one layer after another, going over a part and leaving it and then coming back and going over it until a sufficient thickness is obtained. Can you get a uniform thickness over a large surface with nothing except the eye to guide in producing it? Also, about what is the range of the gun at which one works? For instance, if you want to apply Gunite to the under surface of a roof or the lower part of a bridge, for instance, a height of 20 or 30 ft., would it be necessary to put up scaffolding for such a distance?

Mr. Weber: As to the first question, about the number of coats, the material is seldom put on in one coating. In work where plain finish is required, it is necessary to go within, say, ¼ in. of the final thickness, then float it over and give the finishing coat afterwards. In bridge work, and work where the outside appearance, or rather the appearance of the work itself, is not of so great importance, the coating is, as a rule, put on in one coat and then a light flash coat is used to even up the very rough places.

As to the second question, the height to which we shoot, it is desirable to keep the nozzle within three to five feet from the surface to be coated. Therefore, on the under side of the beams which are of a height, say, over 8 ft. from the ground, it is necessary to build a light scaffold to bring the nozzle within the proper distance from the work.

Mr. Brown: I would like to ask if the author has noticed any difference in regard to the cracking of the plaster or stucco as applied by the gun, compared with hand work?

Mr. Weber: With the ordinary hand work, as a rule, no reinforcement is employed and therefore hand work shows bad cracks, at least in a good many cases. However, Gunite work on wood, which the last speaker apparently means by stucco, is always reinforced with a wire mesh, and as this wire mesh is greatly in excess of the metal required to overcome the temperature stresses of the material, there is little cracking. As a matter of fact, I have yet to see the first crack on a Gunite coat on these structures. This is due to the strength of the coating and the reinforcement. After coating a frame house, we have not a stucco coating, but a thin reinforced-concrete casing over the entire surface, and as there is more reinforcement than would be required for temperature stresses only, there is practically no cracking. I will not say that cracking is impossible. There might be cracks somewhere without my knowing it, but none have ever come to my knowledge.

H. S. Baker, M. W. S. E.: I would like to know whether this cement gun process would be applicable to the repair of a corrugated iron roof. The one I have in mind is made of twenty-gauge black iron, painted and badly corroded, and in places it is so badly rusted you can see through it. How thick a coat would be necessary to insure its being practically self-supporting on a three or four foot span, where the members of the roof would be able to carry a new coating? Have you ever used it for such work?

Mr. Weber: I am quite sure that the cement gun can repair the roof mentioned, and where the sun shines through and the metal in itself is not sufficient to act as a form, it would be comparatively easy to supply additional reinforcement. I believe that a coat of about 1½ in. to 2 in. thickness (depending upon the slope of the roof, the load applied, and several other things), is all that would be required to put this roof in good condition. It is in just such work that the cement gun is of the greatest advantage, practically such work as requires tearing down by any other process. The ability of the gun to go to most inaccessible places and avoid all this tearing down results in great savings.

Mr. Wilson: Would there not be danger of the corrugated iron rusting out underneath, making it necessary for complete reinforcement?

Mr. Weber: We would use the corrugated old roof just for a form on which to place our material, providing reinforcing mesh in the new application. The present metal would be simply a form for the concrete work. If it rusts out, no harm is done, and at the same time this rusting could be counteracted to a certain extent by using a light coat, just for rust protection on the under side. This would also give the additional advantage of taking care of the condensation on the under side of the roofing by providing a rough surface.

J. H. Libberton, ASSOC. W. S. E.: I am interested particularly in the results obtained and in the manner of obtaining them.

The author made the statement that the loss in the application of the sand would vary, I believe, from 5% to 30%, and I am interested to know how, when this loss is so variable, one can make comparative tests between ordinary mixtures and Gunite.

Mr. Weber: You apparently want to know what is the reason for this differentiation in the loss from 5% to 30%.

Mr. Libberton: No, what I wish to know is how you can reconcile these results; for instance, the example you gave; we may start out with 1 to 3 mixture, and assuming a loss of 33% in the sand you end with a 1 to 2 mixture, which, if you compare with the 1 to 3 mixture mixed by hand or by a mixer, is really not fair to the 1 to 3 mixture,—to compare it with the 1 to 2 mixture of Gunite.

Mr. Weber: That is correct, but we have made extensive tests, and to the original mixture the amount of rebound of sand which we expect (and, of course, on account of past experience, we estimate it very closely) is added to the mixture. In other words, to produce a Gunite coating 1 to 3 on the wall, we may estimate an amount of loss of sand by rebound to 20% on a coating 1½ in. thick.

The mixtures on the job are, as a rule, made in small quantities. In order to obtain a uniform final mixture throughout the whole work, it is necessary to make the measuring boxes for the sand correspondingly larger. The correct amount of sand to be used for every sack of cement is determined before the work is started.

Mr. Libberton: You use a leaner mixture then, more sand, when using the gun?

Mr. Weber: Yes. We add to the original mixture the material which will rebound. That is mixing the original mixture leaner, but the ultimate result will be the correct amount for the material on the place of deposit.

Mr. Wilson: How is the gun used on the Panama Canal?

Mr. Weber: Variable use has been found for it, but the first and rather extensive use was had in the Culebra Cut, where the rock is of a very peculiar formation. There is a hard rock on top with an underlying stratum, which the torrential rains and exposure to atmosphere rapidly deteriorate. As this lower material deteriorated and crumbled down, it would undermine the hard rock lying above. It was found necessary to put some kind of a raincoat, as I might call it, over this mass to protect the material, and that is the first use to which the cement gun was put on the Panama Canal. Before they had a cement gun they used form work and applied ordinary concrete of a thickness of from 4 in, to 4 ft., due to the uneven slopes. With the cement gun, such a leveling was not necessary. There was no attempt made to produce an even surface, but simply to cover this, as it was uniformly 4 in. thick. Later the slides of the Culebra Cut destroyed practically all of this work.

Mr. Gaillard: It would not hold the slide back then?

Mr. Weber: No, it was not expected to. The gun is also used on the Canal for finishing cement and other work as in ordinary practice.

Mr. Gaillard: As I understood the matter, the reason they gave up the use of the cement gun in the Culebra Cut was because the rock oxidized behind the coating and the Gunite flaked off.

Mr. Weber: I am not able to make any correction on this statement because it is the first time I have heard it. I really do not know how such an oxidation behind the cement coating could take place, but perhaps in this case the rock is of such a peculiar nature that it would not stand the exclusion of the air.

Mr. Gaillard: It was my impression that it was the natural oxidation of the rock, and that when the rock oxidized it occupied a greater volume than before and really pushed the coating off.

Mr. Weber: Cracks may have appeared, due to the uneven settling, because no attempt was made to reinforce the coating. There are a good many opinions as to what may have caused the breaks and cracks, but that is about the strangest theory I have heard. However, I have no facts in this connection, and therefore I am not able to make any correction.

Mr. Gaillard: It must be remembered that "weathering" on the Isthmus, with its peculiar climatic conditions, is much more severe than is realized by those who are unfamiliar with the conditions there.

Mr. Prior: I would say, in a general way, that rock is not a combustible substance, and if it oxidized at all the process would be slower if well protected by a coating of cement.

Mr. Libberton: I am not familiar with this except what I have heard of the rock formation of the Culebra Cut; but I understand that the inclines there are at a much steeper pitch than the angle of repose, and the rock itself is of a very open nature. If the rock were of a solid formation throughout, the cement gun would absolutely protect the outer area and prevent slides, but with a lot of loose material behind, a thin coat of concrete will not hold it back.

Mr. Gaillard: The following two quotations from the Report of the Geologist, Appendix E, in the Annual Report of the Isthmian Canal Commission for 1912, may be of interest as giving the official reason for the lack of success attending the use of the cement gun under conditions for which it was not, as it turned out, particularly suited. Incidentally they may explain to the skeptical, how rock can oxidize.

"The rocks of the cut are mostly basic, and contain iron and magnesia compound in considerable amounts. The iron compounds are largely in the ferrous form and give to the rocks dark and green shades of coloring. On exposure to the moist atmosphere, these ferrous compounds are oxidized to the ferric condition, with change of volume and consequently a crumbling of the material so charged takes place. This, coupled with the soluble character of the limy cement present in varying quantities in most of the beds, seems to be the chief reason for the very rapid weathering here of all except the dense volcanic rocks."

"It is certain that no practical system of revetment work or retaining walls would prevent the large slides. Still there is no reason why a protecting revetment along the water's edge where the rocks are crumbly, designed to allow for the various rock adjustments, can not be adopted. A thin veneer of cement spread on the slopes from a cement spraying gun was tried, but without success. Within a few months the thin coat of cement thus put on began to crack and peel off, due to the following causes:

"(1) Oxygenated surface waters seeped through the thin coating and through the rock and oxidized the latter along its contact with the cement, thus causing the adhesive zone or contact to become loose and crumbly and very insecure.

"(2) Irregular swelling of the rock, due to oxidation, adjustment of pressures, etc., cracked the cement veneer and further weakened it.

"(3) Blasting vibrations tended to crack and scale it off."

It will be seen that this explanation applies to the places where the banks are unaffected by the slides. Naturally no one expected this cement coating to resist the pressure of the slides themselves, 4 in. is somewhat thin for a retaining wall for a sliding bank some 200 ft. high.

William Seafert, AFF. W. S. E.: Do you lose any cement with the rebound of the sand? The sand must be wet, carried on in a stream.

Another question I would like to ask; how do you try the pressure of the water and the aggregates at the same time? Do you take the city supply, or do you have air pressure behind the water?

Mr. Weber: As to the first question, the loss of cement is ordinarily a negligible amount; in fact, it is such a small percentage that it does not need to be considered at all. For example, if you take, say, a baseball, or any hard body, and roll it in the mud and throw it with very heavy force against a wall, the soft material will leave the ball and splash on to the wall surface. The same takes place on every grain of sand. The impelling force cleans the rebounding sand. Go over our cement work and you find the falling sand at the bottom is perfectly clean, absolutely so.

In regard to the second question, as to how the water pressure is supplied to the material: It is necessary, of course, as you are well aware, to have a higher pressure for the water than for the material. We need about 25 lb. more pressure in the water line than in the material discharge. There are many cases where the pressure in a city water system is 60, 65 and 70 lb.—quite sufficient for cement gun purposes. But if this is not the case, a pump is used in connection with the compressor.

IN MEMORIAM

CHARLES EDWARD DeCROW, AFF.W.S.E.

Died June 17, 1912.

In Charles Edward DeCrow the Society has lost one of those whose loyalty dates back to the early days of the Chicago Electrical Association, long before the latter became the nucleus of our present Electrical Section. Born at Newark, Ohio, in 1871, and trained at Denison University, Mr. DeCrow rose step by step from a track-bonder and dynamo-tender for the Newark & Granville Electric R. R. Co., to a wireman and arc lamp tester for the Western Electric Co., and from operating electrician for Machinery Hall, to electrical inspector for the Transportation Building at the World's Columbian Exposition. Then, after some years' experience superintending electric light plant construction, he returned to the Western Electric Co., where he perfected the organization of the Apparatus Order and Output Department—a notable achievement in itself, and one which led to his further promotion and to his being chosen as General

---

Memoir prepared by Albert Scheible and W. R. Patterson, committee.

Superintendent of the Addressograph Co. some six years ago. This position he retained until stricken with appendicitis last June, from which he never recovered.

Always genial and diplomatic, Mr. DeCrow had the happy faculty of simultaneously making friends of his co-workers and stimulating them to more effective service. Unsparing of his own time and strength, he practiced what he preached, and leaves behind him an enviable record alike for having systematized and improved factory methods, for having inspired a high spirit of loyalty among those working with or under him, and for having been at all times what every true engineer should be—a man among men.

ADAM COMSTOCK, M. W. S. E.

Died August 16, 1911.

Adam Comstock was born at Hector, Tompkins County, New York, September 17, 1827. He was a grandson of Col. Adam Comstock, commissioned Lt. Col. First Rhode Island Volunteer Infantry by the Continental Congress, September 7, 1776.

The father, Alexander McGregor Comstock, pioneer physician, surgeon, and minister of the M. E. Church, removed to Will County, Illinois, at the close of the Black Hawk War, 1836, and the opening work of the Illinois and Michigan Canal. He purchased, cleared, and farmed what is known as Flathead Mound, five miles southwest of Joliet. The settlement house location is still marked by a pile of foundation stones near the late residence of Dr. Rollo Reed on the Channahon Road. On the second outbreak of cholera attending the excavation of the Illinois and Michigan Canal, Dr. Comstock responded to the call to service and unfortunately died in that service from cholera.

Adam Comstock, the Civil Engineer and subject of this memorial, lived with his parents upon the farm until fourteen years of age. In the spring of 1841 the family moved to the village of Joliet. He received his academic education at Mount Morris Seminary, Ogle County, Illinois, and immediately after completing his school work engaged, in 1851, with the Chicago, Rock Island & Pacific Railway on preliminary surveys. He was Resident Engineer during the years 1852-3.

As Resident Engineer, he built the section of the Joliet & Northern Indiana R. R. between Joliet and Matteson, 1854-5, and was subsequently connected with the main line and branches of the Chicago & Alton R. R. He served as City Surveyor of Joliet, from March, 1860, to March, 1868. He also served as County Surveyor of Will County, 1861-69.

In 1869, as Engineer for the Joliet Coal, Iron and Transfer

Memorial prepared by Robert E. Orr, ASSOC. W. S. E.

Co., he laid out the Illinois Steel Works, under Mr. A. B. Meeker, the principal projector. He designed and built the stone arch bridge at Jefferson Street, Joliet, across the Desplaines River, in 1871. This bridge was removed by the Sanitary District of Chicago in 1899.

When the southern states began to recover from the great Civil War, Mr. Comstock was engaged by the Illinois Central R. R. (first as Division Engineer at Clinton, Kentucky, and then as Chief Engineer on location and construction of other lines as far south as Holly Spring), to reconstruct and project new main and branch lines south of the Ohio River, 1871-4. The ill health of his aged mother and her demise in 1874 prevented him from accepting a good position with the Union Pacific Ry. that year. Afterwards he engaged with the city of Cairo, Illinois, and Council Bluffs, Iowa.

It was after the Ute Indian Massacre and the struggle between the Atchison, Topeko & Sante Fe and Denver & Rio Grande railroads over the Grand Canyon Pass, Colorado, that Mr. Comstock engaged with the Denver & Rio Grande R. R. on the firing line in the early eighties to locate and blast their trail through the mountain passes of Colorado. After returning to Illinois he was engaged for a while with the Pekin & Southwestern R. R. and later on a division of the Chicago & Alton R. R. at Higbee, Mo.

In 1886 he was made Chief Engineer of the Texas & St. Louis R. R.

From 1889 to 1893 inclusive he served as City Engineer of Joliet. During this service he became engaged in drainage, water supply, bridge building, and municipal engineering for cities and towns about the State.

From about 1897 until the time of his death he was engaged in independent practice as a Civil Engineer.

In 1853 Mr. Comstock married Miss Elizabeth E. Griffin, of Moline, Illinois. In 1888 he suffered the loss of his only son, W. E. Comstock, who was also a Civil Engineer. In 1905 the loss of his devoted wife was another heavy blow. An only daughter, Mrs. William E. Sandiford, of Joliet, survives him.

Mr. Comstock was a charter member of the Western Society of Engineers and retained a continuous membership until his death in 1911.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Regular Meeting, March 2, 1914.

A regular meeting (No. 853) was held Monday evening, March 2, 1914. The meeting was called to order by President Lee at 8:10 p. m., with nearly 200 members and guests in attendance. The Secretary reported from the Board of Direction that the following had been elected into membership:

1913		
No. 158,	Arthur B. Shenk, Evanston, Ill.	Junior Member
No. 166,	Edward E. Reddersen, Chicago (transfer)	Junior Member
No. 167,	Bert H. Peck, Chicago	Associate Member
1914		
No. 1,	Harold P. Weaver, Chicago (transfer)	Associate Member
No. 3,	Barnabas Schreiner, Oskaloosa, Iowa (transfer)	Member
No. 5,	Royal H. Drummond, Fargo, N. D.	Student Member
No. 6,	William Otto Lichtner, Newton Highland, Mass.	Associate Member
No. 7,	Herbert E. Hudson, Chicago	Associate Member
No. 8,	Isaac Van Trump, Chicago	Member
No. 9,	William H. Fursman, Henryetta, Okla	Member
No. 10,	Henry Ericsson, Chicago	Member
No. 11,	Arnold N. Lurie, Chicago (transfer)	Associate Member
No. 12,	Frederick T. Synder, Chicago	Member
No. 13,	Henry J. Kaufman, Chicago	Member

Also, that applications for admission to the Society had been received from:

1914
No. 14, Carl E. Brockhausen, Chicago.
No. 15, Edward C. Holden, Chicago.
No. 16, Francis H. Wright, Chicago.
No. 17, James Sorenson, Milwaukee, Wis.
No. 18, Charles A. Morse, Chicago.

The President then introduced Mr. A. S. Zinn, M. W. S. E., who addressed the meeting, with lantern slide illustrations, on the Panama Canal, Locks and Spillways. In turn Mr. Zinn introduced Mr. L. D. Cornish, the designing engineer of the same, who described, somewhat in detail, the locks of the Panama Canal.

After a little discussion, and a social time, the meeting adjourned about 11 p. m.

Extra Meeting, March 9, 1914.

An extra meeting of the Socety (No. 854)—the Bridge and Structural Section—was held Monday evening, March 9, 1914. The meeting was called to order at 8 p. m. by the Chairman, Mr. J. H. Prior, with about 75 members and guests in attendance. The idea of convening the meetings of the Section at an earlier hour was presented, discussed, and on vote it was decided to have the meetings of this Section begin at 7:30 p. m.

Mr. Carl Weber was introduced, who read his paper on "The Cement Gun." Discussion followed from Mr. Prior, R. S. Draper, E. B. Wilson, C. W. Boynton, C. W. Melcher, O. F. Dalstrom, Mr. Brown, H. S. Baker, Ernest McCullough, J. H. Libberton, D. P. Gaillard, Geo. M. Mayer, Wm. Seafert, with replies and explanations from Mr. Weber.

Meeting adjourned about 10 p. m.

Extra Meeting, March 16, 1914.

An extra meeting of the Society (No. 855) was held Monday evening, March 16, 1914. The meeting was called to order at 8:05 p. m., Mr. B. E. Grant presiding, and with about 140 members and guests in attendance. Mr. Andrew Cooke was introduced, who read his paper, Government Regulation of Railroads from the Investor's Standpoint. He was followed by Mr.

Samuel O. Dunn, Editor of the *Railway Age Gazette,* who read his paper on Valuation of Public Utilities from the Railway Point of View. He was folowed by Mr. Harold Almert, on Public Utility Regulation from the Standpoint of the Public and the Engineer. Discussion followed from Messrs. J. W. Alvord, W. B. Jackson, W. A. Shaw, L. E. Cooley, A. C. King, B. E. Grant, and Prof. Morgan Brooks. The Secretary read a discussion of the subject sent in by letter from Mr. Onward Bates.

Meeting adjourned at 10:20 p. m.

Extra Meeting, March 26, 1914.

An extra meeting of the Society (No. 856), a joint meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., was held Thursday evening, March 26, 1914.

The meeting was called to order at 8:10 p. m. by Mr. F. J. Postel, Chairman of the Electrical Section, and with about 100 members and guests in attendance. Mr. R. H. Rice, on behalf of the A. I. E. E., stated that an effort was being made toward increase of membership in the A. I. E. E. by the several local sections, and it was for the members of the Chicago Section to decide upon their plan of action. Also that the next meeting of the Chicago Section, April 27th, would be the Annual Meeting and election of the Executive Committee of the section.

Mr. B. H. Glover, of the Underwriters Laboratories, was then introduced, who read his paper on the duties and services of the laboratory, particularly as relating to Electrical Inspection. Discussion followed from Messrs. V. H. Towsley, electrical inspector for the city, and H. B. Gear of the C. E. Co. There was other discussion from B. H. Peck, R. S. Huey, S. S. Wendt, F. A. Watkins, C. W. Naylor and P. B. Woodworth, with replies and explanations from Messrs. Glover, Towsley and Postel.

Meeting adjourned about 10:10 p. m.

J. H. Warder,
Secretary.

BOOK REVIEWS

The Books Reviewed Are in the Library of This Society.

Economics of Interurban Railways. By Louis E. Fischer, Consulting Engineer, St. Louis, Mo. McGraw-Hill Book Co., New York, 1914. Cloth, 5 by 7½ in. 116 pp.. including index. Price $1.50.

The interurban railways considered in this little book are electric railways, the promotion and construction of which have been noticeable features in the industrial and financial world within the last few years. There are now over 20,000 miles of electric roads, suburban and interurban, in operation in the United States. The operations of these are more or less available through the medium of reports of State Commissions, yet these reports are not always of service in showing a possible investor whether a newly projected road would prove to be a profitable one. As a matter of fact, many of these properties have been unprofitable. There is a strong similarity here with the history of steam operated railroads, and this similarity leads to some suspicion on the part of those to whom new projects along these lines are presented, soliciting their financial aid. It is because of this condition that the author considered there was need for a review of economic results of the operations of electric interurban railways, that a layman may better comprehend the fundamentals pertaining to an economically successful road.

The book is divided into seven chapters, with somewhat the following divisions: Inception and Development of Electric Traction; Classification and Definitions; Operating Revenue; Operating Expenses; Cost of Construction; and, Economic Relations of Revenues, Expenses and Construction. Some interesting tables are presented, as Table I, "Passenger Revenue," and "Other than Passenger Revenue" for ten typical selected cases. These ten roads show an aggregate Passenger Revenue of $614,208, and from Other than Passenger Revenue an aggregate of $60,428, or a total gross revenue for the ten roads of $6,913.21. The mileage of these ten roads is not given, but for comparison there is a statement that in 1911 the average on 243,229 miles of steam roads the passenger revenue was $631,340,776, and the revenue other than passenger (freight, express, etc.) aggregated $2,155,338,840, or 77 per cent of the total gross revenue, which was about nine times the corresponding figure of the ten electric roads. The author has classified electric roads according to the terminal and subsidiary population to be served, and from whom the revenue is to be obtained. A table is presented of statistics of 36 typical electric lines, in 13 different states, with the miles of track of each, the primary terminal population, the intermediate town and village population and the gross operating revenue, from which the author draws the deduction that operating revenue varies with the aggregate of the intermediate town and village population. There are other tables presenting data of a somewhat similar character and which are of value to enable a forecast to be made as to the probable earnings on a projected electric road. Other tables show operating expenses of electric interurban railways of one character or another, and referred to car mile or other basis. Also taxes in different states, total and per mile of track, which show for 10 electric roads an average of $156.00 per mile of track and that $448.00 is the average taxes on 243,229 miles of track of steam roads in 1911.

The book possesses a distinct value to those interested in electric roads, projected or in operation.

THE MECHANICAL ENGINEERS' REFERENCE BOOK. A handbook of Tables, Formulas and Methods for Engineers, Students and Draftsmen, by Henry Harrison Suplee, B. Sc., M. E. Lippincott & Co., London and Philadelphia. Flexible leather; 4 by 7 in.; pp. 964. Price, $5.00.

This Mechanical Engineers' Reference Book, which appears in its fourth edition, will undoubtedly meet with much favor among the mechanical engineering profession. The text, which has been extensively revised and enlarged from the one of the three previous editions by the addition of a 40 page appendix, is presented in a precise and comprehensive manner which makes it easy to find just what one is looking for when referring to the book for information.

The first chapters on Mathematics, Mechanics and Materials of Engineering contain mostly tabulated matter conveniently arranged for ready reference. Under the heading of "Standard Flanges" the old standards of the American Society of Mechanical Engineers from the year 1900 have been given, and the reviewer wishes to suggest that the latest "Standard" adopted by the American Society of Mechanical Engineers, Oct. 25, 1911, may have been included to advantage in the text, together with the other standard. The chapters on Strength of Materials and Machine Design are very well treated, covering briefly the essential points with which the designer comes in frequent contact in his daily work.

The chapter on heat is treated in a rather general way and in the reviewer's opinion the future editions of this book could include more data on the important subject of Heat and Heat Energy.

The chapters on Air and Water contain 80 pages of very useful information. Fuel and steam are really too briefly treated in order to be considered of equal value with the balance of the text matter. The tabulated data on fuel could also have been revised by including more recent tests and analyses than those published in the previous editions. The chapters on Steam Boilers, Steam Engines, Internal Combustion Motors, and Electric Power are sufficiently complete for a book for such purposes for which this book is intended. The balance of the book is well in keeping with the general excellence, and while the reviewer has not chcked any formulas given in the book he has nevertheless recognized quite a number which are authoritative in their respective place.

One especially desirable feature of this book is the tabulated data in Metric Units which render it very convenient to change calculated data from one system of measurements into the other.

In general, this book can be heartily recommended to every engineer, not only mechanical, but also electrical and civil, as in spite of the era of specialization in the engineering profession, the time has arrived in which we must not only know as much as possible about our own line of work but must also be posted to a certain extent about the work of our brothers in the field, and, therefore, this Mechanical Engineers' Reference Book should have a place on the desk of every engineer. R. G. R.

INDUSTRIAL CHEMISTRY FOR ENGINEERING STUDENTS, by Henry K. Benson, Ph. D., Professor of Industrial Chemistry, Univ. of Washington. The MacMillan Company, New York. Cloth, 5 by 8 in.; pp. 431. Price, $1.90.

Industrial Chemistry is a brief treatise of the chemistry of the more common materials used in the various branches of engineering and although brevity by itself without adequacy is questionable, it must be said about this book that Professor Benson has sacrificed no salient feature that is essential. As the title states, this book is chiefly intended for engineering students and a thorough study of the book should not fail to provide a foundation broad and thorough enough to serve as an introduction to a more advanced study of the subject.

The more important topics of interest in engineering, like fuels, combustion, clay products, cement, and explosive materials are more fully covered than some subjects not as important. This book, while primarily intended for students, will be found very useful by the practical man, and especially the man in charge of a power plant, or the heating and ventilating engineer. To understand this book, a knowledge of elementary physics and the first principles of chemistry are pre-supposed.

An important feature of the book, in the opinion of the reviewer, which will be very useful for those desirous of pursuing the study of a special subject, is the bibliography at the end of each chapter. This is very complete and only reliable information has been used. The system in which these bibliographies are listed,—first the books, alphabetically by authors, and then the titles of books or articles in chronological order,—makes a reference to the same very convenient.

A critical review gives the impression that the author has accomplished his purpose of providing, with the presentation of this book, a selection of subject matter which will benefit both the students of engineering and the practician as well. R. G. R.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts the following publications have been received:

NEW BOOKS.

M. C. Clark Publishing Co.:
- Steel Bridge Designing, M. B. Wells. Cloth.
- Inspection of Concrete Construction, Jerome Cochrane. Cloth.

Purchase:
- Bridge Engineering, Roof Trusses, F. O. Dufour. Cloth.
- Rational and Applied Mechanics, Calvin M. Woodward. Cloth.
- The Steam Turbine, James A. Moyer. Cloth.

MISCELLANEOUS GIFTS.

Arthur H. Blanchard:
- Specifications for Types of Roads and Pavements and Materials of Construction for use of New York State Highway Dept. Pam.

C. K. Mohler, M. W. S. E.:

Report No. 1 on Valuation of Street and Interurban Lines in Los Angeles, Cal. Pam.

Isham Randolph, M. W. S. E.:
- The Imaginative Faculty in Engineering. Pam.

Daniel M. Brady:
- The Past, Present and Future of Railway Clubs, Brady. Cloth.

Samuel S. Wyer:
- Report on Electrolysis Conditions in Springfield, Ohio. Pam.

Citizens Terminal Plan Committee, Chicago:
- Report of Walter L. Fisher and Bion J. Arnold to Committee. Pam.

H. W. Caldwell & Son Co.:
- General Catalogue No. 38. Cloth.

Scherzer Rolling Lift Bridge Co.:
- Scherzer Rolling Lift Bridges. Cloth.

Howard Logan, M. W. S. E.:
- The Fight for Conservation, Pinchot. Cloth.
- The Conservation of Natural Resources in the United States, Van Hise.
- The Conservation of Water, Mathews. Cloth.

EXCHANGES.

Providence, R. I., City Engineer:
- Annual Report for year of 1912. Pam.

Society of Engineers:
- Transactions for 1913. Cloth.

Liverpool Engineering Society:
- Transactions, 39th Session, 1912-13. Pam.

Institution of Civil Engineers:
- Minutes of Proceedings, Vol. CXCIII. Paper.

North-East Coast Institution of Engineers and Shipbuilders:
- Transactions, 29th Session, 1912-13. Cloth.

Iowa Railroad Commissioners:
- Report, 1912. Cloth.

American Electrochemical Society:
- Transactions, 1913. Pam.

American Society of Mechanical Engineers:
- Year Book, 1914. Cloth.

American Society of Civil Engineers:
- Year Book, 1914. Cloth.

Iowa Geological Survey:
- Bulletin No. 4, Weed Flora of Iowa, 1913. Cloth.

Illinois State Geological Survey:
- Bulletin No. 22, Oil in Crawford and Lawrence Counties. Cloth.

GOVERNMENT PUBLICATIONS.

Benj. C. Humphreys, M. C.:
- Floods and Levees of the Mississippi River. Cloth.

U. S. Bureau of Mines:
- Bulletin No. 58, Fuel-Briquetting Investigation, 1904-12. Pam.
- Bulletin No. 60, Hydraulic Mine Filling. Pam.

Interstate Commerce Commission:
- 27th Annual Report, 1913. Cloth.

U. S. Geological Survey:
- The Production of Spelter in the United States in 1913. Pam.

U. S. Bureau of the Census:
- Benevolent Institutions, 1910. Cloth.

U. S. Bureau of Standards:
- Technologic Paper No. 18, Electrolysis in Concrete. Pam.
- Technologic Paper No. 25, Electrolytic Corrosion of Iron in Soils. Pam.

U. S. War Department:
- Report of the Tests of Metals and other Materials, 1913. Cloth.

March, 1914

MEMBERSHIP

Additions:

Drummond, Royal H., Fargo, N. D.	Student Member
Ericsson, Henry, Chicago	Member
Fursman, Wm. H., Henryetta, Okla	Member
Hudson, Herbert E., Chicago	Associate Member
Kaufman, Henry J., Chicago	Member
Peck, Bert H., Chicago	Associate Member
Shenk, Arthur B., Evanston, Ill	Junior Member
Snyder, F .T., Chicago	Member
Van Trump, Isaac, Chicago	Member

Transfers:

Lurie, Arnold N., Chicago, Junior to	Associate Member
Reddersen, E. E., Chicago, Student to	Junior Member
Schreiner, B., Oskaloosa, Iowa, Associate to	Member
Weaver, Harold P., Chicago, Junior to	Associate Member

Deaths:

Draper, Robert Strother, Chicago, March 17, 1914.

Dupl [illegible]

VOL. XIX, No. 4. APRIL, 1914

JOURNAL
OF THE
WESTERN SOCIETY
OF
ENGINEERS

CONTENTS

City Transportation,—Subways and Railroad Terminals.
Bion J. Arnold 325
Discussion:
By R. F. Schuchardt, M. M. Fowler, James J. Lyman, F. E. Davidson, A. Bement, E. N. Lake, Mr. Federman, G. C. D. Lenth, G. F. Vent, J. R. Bibbins and the author.
Wind Loads on Buildings. Albert Smith 369
Discussion:
By J. H. Prior, J. W. Pearl, Andrews Allen, Edwin A. Howes and the author.
The Making of a Technical Journal. E. J. Mehren 393
Memorials—
Robert Strother Draper 404
Abel O. Anderson 405
Proceedings of the Society, Minutes of Meetings 406
Book Reviews 408
Library Notes 410
Membership 412
Index to Advertisers XXII

CHICAGO

Published Monthly, Excepting July and August, by the Society,
1735 Monadnock Block.

Entered as Second-Class Matter March 3, 1896, at the Postoffice at
Chicago, Ill., under Act of March 3, 1879.

Subscription Price, $3.00 per Volume of Ten Numbers.

50 Cents a Single Number.

Copyright, 1914, by the Western Society of Engineers.

WESTERN SOCIETY OF ENGINEERS

1735 Monadnock Block, Chicago, Illinois.
Phone Harrison 945.

OFFICERS FOR 1914.

President...E. H. Lee, Dearborn Station
First Vice-President........................B. E. Grant, Room 207 City Hall
Second Vice-President.........Ernest McCullough, 1308 Monadnock Block
Third Vice-President.........................G. F. Gebhardt, Armour Institute
Treasurer........................C. R. Dart, Room 700, 900 Michigan Ave.
Trustee........................J. G. Giaver, 1 year, 1417 Railway Exchange
Trustee....................F. E. Davidson, 2 years, 1448 Monadnock Block
Trustee.................................H. S. Baker, 3 years, 408 City Hall

Past Presidents on the Board of Direction.

O. P. Chamberlain.......................108 So. La Salle St.
W. C. Armstrong.......................226 W. Jackson Blvd.
Albert Reichmann.........................72 W. Adams St.

ELECTRICAL SECTION

Executive Committee

F. J. Postel, Chairman; H. M. Wheeler, Vice-Chairman
G. T. Seely...1 year
P. B. Woodworth......................................2 years
E. W. Allen...3 years

BRIDGE AND STRUCTURAL SECTION

Executive Committee

J. H. Prior...Chairman
J. W. Musham......................................Vice-Chairman
E. N. Layfield   H. C. Lothholz   I. F. Stern

HYDRAULIC, SANITARY AND MUNICIPAL SECTION

Executive Committee

W. D. Gerber..Chairman
G. C. D. Lenth......................................Vice-Chairman
W. W. DeBerard   Douglas Graham   Langdon Pearse

Secretary............J. H. Warder

The Chanute Medals

The Board of Direction, W. S. E., desire to announce that the Octave Chanute Medals will be awarded for the most meritorious papers on Engineering subjects presented before this Society by members thereof during the year 1914.

Journal of the
Western Society of Engineers

VOL. XIX APRIL, 1914 No. 4

CITY TRANSPORTATION—SUBWAYS AND RAILROAD TERMINALS

BION J. ARNOLD, M. W. S. E.

*Presented January 26, 1914.**

In 1902 the City of Chicago entrusted me with the responsibility of making a study of the then transportation system of the city; that is, that portion of it which related to the surface lines companies. I had five months in which to make the study and make the report. That report was delivered in November of that year.

The present underground freight tunnel system, known at that time as the Illinois Tunnel Company and now as the Chicago Tunnel Company, had then about six miles of the small bore size constructed and the promoters or the owners had asked the City Council for the privilege of enlarging that bore. They had constructed short sections of an enlarged size, one in front of the Masonic Temple, and the other on Fifth Avenue, I think, between Monroe and Madison Streets. They had these little sections, each probably 80 or 90 ft. long, to show that they could build a hole of that size under the Chicago streets at that level. They had come before the City Council and asked permission, as I say, to enlarge the bore of the entire system to that size, which is large enough to allow a street car to run in,—that is, a properly designed street car to fit that particular tunnel. Nevertheless, it would have been a car large enough to have transported passengers and would have resembled the cars now operated on what is known as the London and Waterloo Road, running from the Bank of England over to Waterloo Station. They are very low. The wheels are low; the cars are low in the frame, and they are squatty in appearance. But they carry passengers successfully. Such a car could have been operated had the subway been constructed to the size of those large sections then built.

At that time the question I was asked by the City Council to report on was whether this company should be allowed to enlarge its section to that size. I asked for time, saying that the transportation problem of the city had just been put up to me, and I thought I ought to have time to analyze the entire problem before making a reply. They gave me that time and when my report was delivered, it was adverse to the enlargement of the tunnel, unless the representatives of the company would come out squarely and say what they wanted it for. The theory they claimed to want to enlarge it on was this,—that the tunnel was built for telephone cables, and that they had found they could more economically construct telephone cables in mile lengths than in any other lengths, or at any rate they could buy them cheaper in mile lengths; also, it would save joints if they could buy the cables in that length, and in order to get a reel in the tunnel big enough to carry a cable a mile long, they must have the tunnels the large size. I saw the argument, but I did not see the proof of the necessity for the large tunnel, and so I reported adversely as to the enlargement of it unless they would say frankly they wanted it for street cars, in which case it would have been a matter of negotiation with the city for street car service, and it might have been a good thing. But after opposing me for four or five months, after my report came out they came to the conclusion they did not want to enlarge that tunnel, and came around and said if I would say to the Council that a small tunnel, such as they then had six or seven miles built, would not interfere with the subway I thought the city ought to have for street car purposes, they thought they could get their ordinance, and would I please look into it and see if I could conscientiously say so to the City Council. I made a few extra calculations and found that while it did cut into the double-decked system as I had planned it then, the difficulty could be overcome. I do not mean double-decked except where the subways crossed at different levels. I found by raising the lower subway six or eight inches I could, by special designing, allow the Illinois Tunnel Company as then planned with its small bore to stay at its then level. I so reported, and the Council passed the ordinance after adopting the further suggestion which I made and which was written into the ordinance, to the effect that if at any time in the future the city desired to construct subways, the Illinois Tunnel Company would move its structure out of the way of the subways, free of cost to the city of Chicago at such points as it might interfere with the city's subways.

---

*Stenographic report of an informal talk by Mr. Arnold before a Joint Meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E.

Thus we are in a position to construct subways and to require that company to remove its subway where it is necessary; but several million dollars have been put into it, and I believe it is no man's duty, and neither should he attempt, to destroy property if that property can be made to serve a useful purpose. Consequently, I do not believe any man should design a system of subways in the city of Chicago with the deliberate intent of wrecking that property; and in all my designing I have planned to interfere with the property of the Illinois Tunnel Company as little as practicable. There are certain places where it will have to be slightly interfered with, but, as I will show you later, we have planned to leave their levels practically as they are, only slicing off roofs at certain sections and then introducing special steel construction in order to get the low level subways sufficiently low to allow the high level subways to pass over them and beneath the surface of the streets.

Remember, we have but 33 feet from the top of the Illinois Tunnel to the surface of most of the streets, into which we must get the crossings of two subways if we want to avoid grade crossings, and I think we should adhere to the principle of the absolute elimination of grade crossings under ground in all the new subways.

In 1911 the city of Chicago again asked me to analyze the subway problem, and as chief subway engineer for the city I prepared a report and delivered it to the administration then in power.

I want to read a page or two from that report to show you the conclusions I came to then, and it also sets forth the principles that I still think should govern the subway system for the city.

> "The problem of preparing working plans at the present time for a subway" (that is, 1911) "for the city of Chicago is especially difficult, not only because of the physical difficulties introduced by the existence of the present Illinois Tunnel, consisting of about 60 miles of freight tunnel"—

(Remember, it had grown from six miles in 1902 to about sixty miles in 1911 and since, so that we now practically have a small tunnel under almost every street in our downtown district and extending considerably out into the outlying districts.)

> "which, in general, is but 33 feet below the surface of the streets, thereby almost prohibiting the building of a comprehensive subway system between this tunnel and the surface of the streets without introducing the dangers incident to the use of grade crossings, but also from the further fact that the policy of the city is not yet settled as to the method of financing subways. Some of the citizens of Chicago advocate the construction of municipally-owned subways, independent of the present traction companies, while others seem to be in favor of granting ordinances for the construction of privately-owned subways, also independent of the present traction companies. A further complication is introduced by the traction settlement ordinances of February 11, 1907, under which the surface lines are operating, having a provision whereby the surface line companies are required, upon the demand of the city, to furnish money toward the construction of subways, provided, however, that these companies have the full use of the subways so constructed, up to the capacity that they require, and the advocates of the municipally-owned subways oppose the acceptance from the surface line companies of any money for the construction of subways.

> "With the above facts in mind, in order to produce plans which will meet all reasonable and fundamental objections likely to arise during the discussion and final determination of the city's subway policy, as well as the engineering and operating conditions which will be imposed upon a subway system when built, it has seemed necessary to prepare plans for two distinct systems, but to recommend the one which seems the better on the theory that the policy of the city should be made to fit the better plan, although leaving the city free to adopt the other plan if this theory proves incorrect and the plan recommended cannot be put into practice."

That is exactly the problem we have before us now; that is, which one of the plans are we to put into practice?

Bear in mind that I have them so interlaced that you can put either one or parts of either one into practice as you choose, and so that these parts can finally become parts of a comprehensive system.

> "Plan No. 1 is for a high-speed, comprehensive system, designed to ultimately cover the entire city, in which could be operated high-speed and local trains, independent of any of the present traction companies."

Remember, that was my recommendation in 1911 as Plan No. 1.

> "This system could be built by the city or by private capital, without the use of any money from the present surface line companies, or by utilizing this money if the city decided to do so. Upon the tracks of this subway could at first be run the present surface line cars, later the trains of the present elevated roads, and finally, when extended, the trains of a high-speed, comprehensive subway system covering the entire city, thus making it possible to promptly relieve the present surface line congestion at moderate cost by constructing only a portion of the system at first, and later to eliminate the entire present elevated loop structure, if conditions should come about so that this could be accomplished, and at the same time have the nucleus of a high-speed subway system, which could be extended from time to time, as the conditions warranted, until it covered the entire city, approximately as shown on Map VII. This plan, for convenience to the general public and from an investment and operating viewpoint, would be the most econominal plan to adopt, and is shown in its progressive steps, or stages of construction, on Maps (of 1911 report) I, II, III, IV, V, VI, VII, and VIII, which will be described more in detail hereafter."

Plate I shows Map I of my 1911 report. The plan I then recommended was a subway on Clark Street, from 22nd Street, running straight north to Madison Street. Then I ran it westward on Madison to LaSalle Street, thence north on LaSalle Street, under the river, through the LaSalle Street tunnel. This is practically the first step that the Board of Supervising Engineers recommended recently, except that we extended the line straight north on Clark Street. The dotted lines in that central loop show the then recommended portion of the West Side loop; the West Side cars then could be taken in through the Washington Street tunnel, thence east to Michigan Avenue, and back in Jackson Boulevard to a connection with the Van Buren Street tunnel. Thus the northbound cars were intended originally to run on Clark Street to Madison, then jog westward to the LaSalle Street tunnel and out to the surface at the portal just north of the river. Recently the Board thought best to keep the Clark Street line absolutely straight, and having more money available we concluded not to make the jog so as to use the Washington Street tunnel, but to run straight through in Clark Street and build a new tunnel, running the subway as far north, according to our original recommendation, as North Avenue. The Council Committee, in order to save money, have shortened that tentatively. They have not, in my judgment, absolutely decided to shorten it, because it is possible we may be able to show them that it is advisable not to shorten it; but at the present time the plan they have adopted is with this north portal withdrawn southward to what is known as Elm Street, where the traction company has property in which a portal could be constructed. That is one of the main reasons they went back to that point. The south point is just south of 18th Street, instead of 22nd Street, because we can get the cars away from the subway a little better at the former point.

Plate II represents what we called the initial step of a system, designed to relieve congestion on the surface car lines at the present time. A portion of it, namely, that portion in Clark street, is so constructed that it can become ultimately a part of a comprehensive high-speed subway system. The loop from the West Side, however, is fundamentally a surface line congestion relief system—I will put it that way—designed fundamentally for the surface line cars.

In order to relieve congestion at other portions of the city, where we think some money spent at the present time will be beneficial to the citizens in general, and especially to the citizens of the West Side, we have suggested that five short subways be built, one on south Robey Street, from 39th Street to 46th Street (shown on Plate III), on account of the Ashland Avenue railroad switchyards. If this subway were constructed, and also two others on Robey Street (Plate IV), there could then be opened up a straight north and south street car line on Robey Street, which would be of great advantage. Plate III also shows another short subway which we have advocated on California Avenue, extending from Grand Avenue to Fulton Street, which will serve the same purpose for California Avenue that the Robey Street tunnels are meant to serve—that is, of opening up the street under the railroad yards, where the street is not now opened, thus making it possible to have another north and south through-route street.

Plate IV not only shows two of the three short subways on Robey Street referred to, but also another short subway on Ashland Avenue, thus opening up Ashland Avenue the same way that the other streets were opened.

As previously stated, Plate I shows the plan recommended in my 1911 report as Step No. 1. I will not describe it further than to say that at the present time the Board has recommended that the line come straight east on Washington Street to Michigan Avenue, thence south on Michigan Avenue and west on Jackson Boulevard to the Van Buren Street tunnel, as shown on Plate II. You will see that the Clark Street line is straight and that the jog to Madison Street has been eliminated. It is not necessary to discuss that further.

Plate V shows the relative locations of the subways shown on Plates II, III, and IV, and in addition certain extensions are shown dotted, that have been considered by the Council Committee.

Plate VI shows what I called Step No. 2 in my 1911 report, and consisted of a double-tracked subway on State Street, beginning about 12th Street, one line for the surface line cars, running straight north on State Street to Chicago Avenue, and out through a portal at that point. Thus, the surface line cars could converge at this portal, run south in State Street, come out at 12th Street, and then diverge on to the various surface lines. In like manner, the elevated cars from the South Side would come into this subway about 12th Street, then run north to Chicago Avenue, and thence west under Chicago Avenue to a connection with the Northwestern elevated road. In that way it was possible to through-route the North Side and South Side elevated cars. Through-routing over the elevated structure has since, however, been put into use by the elevated lines themselves; consequently one of the advantages of this subway has been achieved, but the capacity would be still greater if we had such a subway.

In order to take care of the West Side elevated cars and give each one of them a route, as they were independently owned at that time and had not been consolidated as they have since, I planned a subway loop, beginning about Sangamon Street, thence eastward on Randolph Street to Michigan Avenue, south to Madison Street, and thence back, a double-track loop, making it possible to run cars both ways on that loop. In like manner, a similar loop was provided for the Metropolitan system, coming east from about Peoria Street on Harrison Street to Michigan Avenue, north on Michigan Avenue to Jackson Boulevard, west on Jackson Boulevard to Peoria Street, thence connecting with the elevated structure. Thus, we have north and south elevated cars, running north and south through the city, and east and west elevated cars intersecting them, with transfer points on State Street at four different stations.

Step. No. 3 (Plate VII) was simply a portion of what I have just described, leaving out the independent loop feature for each elevated road by omitting the subway under Madison Street and Jackson Boulevard. It is probably unnecessary to describe that further than to say that it came east under Randolph Street to Michigan Avenue, south under Michigan Avenue to Harrison Street, and west under Harrison Street to the elevated structure; and since the lines have been consolidated, that is probably the preferable scheme to adopt now, rather than the two-loop system which I have just described.

Step No. 4 (Plate VIII) was to extend the Chicago Avenue subway through and under the river to a portal west of the river, at Green Street. Thus, surface cars could come in on Chicago Avenue, run east to about State Street, thence south under Michigan Avenue to 12th Street, thence west to a portal in the vicinity of Newberry Street. Of course, the necessity for that is some time ahead.

In Plate IX we have a combination of the various steps. First, the original step under Clark and LaSalle Streets, also the surface line loop; then Step No. 2 of the elevated, and the north and south State Street subway.

In Plate X all the schemes are shown together. In this you will notice the same U, giving the same surface congestion relief loop that the Board has recently recommended, namely, coming straight east under Washington Street to Michigan Avenue, south under Michigan Avenue to Van Buren Street, thence back under Van Buren Street, except that instead of coming west under Van Buren Street we recommended coming back to the Van Buren Street tunnel under Jackson Boulevard, and then out. Please note that all of these West Side lines come as far east as Michigan Avenue,.and with a station which I will describe to you later, a universal transfer point was arranged on Michigan Avenue, so that it would be possible for passengers to get from any part of the city to any other part of the city by coming to this point and transferring, although many would be able to go in some shorter way.

The system which I have just described could be extended into a comprehensive system, as shown in Plate XI, which is Map VII of my 1911. report. You will notice that I have a four-track subway in Halsted Street, running straight north and south as far as the street extends. Then I had State Street occupied by a four-track subway, as shown. Then the Michigan Avenue clearing station. In a general way, that system would still hold, I think, if it were necessary to expand it to that extent. Please note that the Clark Street subway which we are now recommending, if extended north would continue extended in Lincoln Avenue to the city limits if desired. If extended southward, it would continue out Archer Avenue. Thus, we would eventually have a high-speed U-shape subway running through the heart of the city under Clark Street

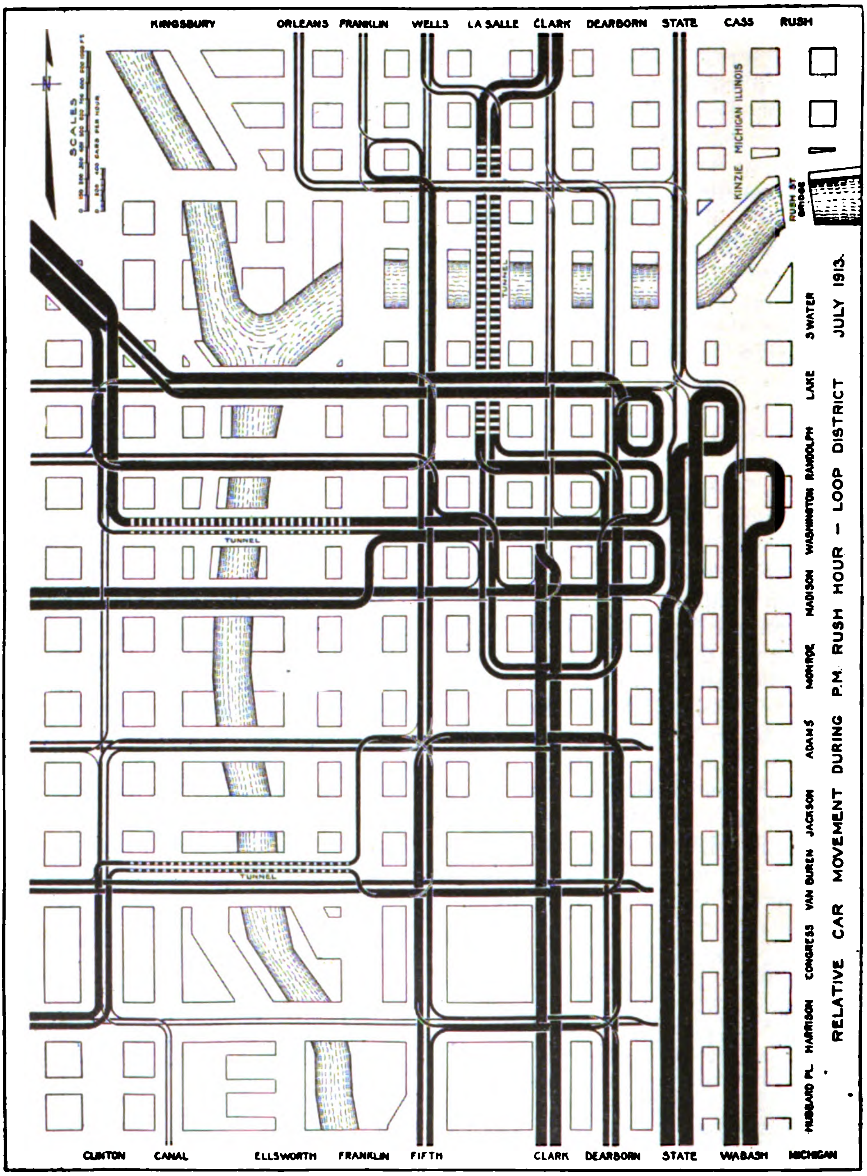


PLATE 12. STREET CAR FLOW DIAGRAM.

This diagram, taken from the annual report of the Board of Supervising Engineers, Chicago Traction, shows the street car movement over various streets in the congested district during the rush hour. Note the forced concentration of traffic on the available thoroughfares, particularly toward the south and west, which is rapidly approaching a point where additional outlets from the business district will be absolutely necessary. Fortunately the passage of the recent unification ordinance by the Chicago City Council will facilitate the through routing of cars and greatly help the situation.

and extending out under Lincoln and Archer Avenues. In the same way a subway could eventually come up Cottage Grove Avenue to Michigan Avenue and thence northward, connecting with the Evanston Division of the Chicago & Milwaukee Electric Railway. In like manner it would also connect with the Northwestern Elevated Railroad. These little pieces which I have described hitch up to a through-route scheme in the same way in this general plan.

Plate XII is a map showing the street car traffic as it now flows on our surface line system with independent operation. The heavy lines show the cars which loop in the downtown district and go back. The lighter lines show the through-route traffic; that is, the number of cars that are through-routed. They are comparatively small; that is, the line is comparatively thin, while the heavy lines come in from Milwaukee Avenue and loop from this point back. Similarly, the line under Madison Street. I am showing you this diagram to bring to your attention the great number of turns we have in the business district, almost all of which, in fact, are unnecessary. A properly constructed subway system on the through-routing principle would largely eliminate these unnecessary turns, and they will be largely eliminated as soon as the new unification ordinances of the surface line companies go into effect. Gradually as schedules can be worked out, the surface lines of the city will be operated on the through-route principle. Then this congestion shown on the map will largely disappear without any subways at all, although we shall still be hampered for tracks on which to operate the cars. Consequently, there are certain places where subways are desirable in order to get the capacity of these additional tracks.

Plate XIII is the subway system designed as I would like, as an individual, to see it worked out now. I am not speaking now as Chairman of the Board of Supervising Engineers, because as a Board we try to have harmony, and when we make a recommendation we aim to have it represent the views of all of us, or of a majority at any rate. I am hoping the City Council will consider this plan seriously, when suggestions regarding it are made before the Committee at the right time, and also that they will find money enough to build it.*

At the present time, and in all its recent recommendations, the Board has been handicapped by the fact that it is confined to the limitations of the 1907 ordinances. Those ordinances define very clearly the duties of the members of the Board, the scope of its duties, and also have very definite provisions for the construction of subways, which subways are to be used by the surface line companies if they are to be constructed under those ordinances. Consequently, all the recommendations that the Board has made upon the question of subways have been restricted to the limits of the authority given

---

*Since this discussion took place the Council Committee adopted Mr. Arnold's suggestion for the "Initial Subway Plan," as shown on Plate XIII.

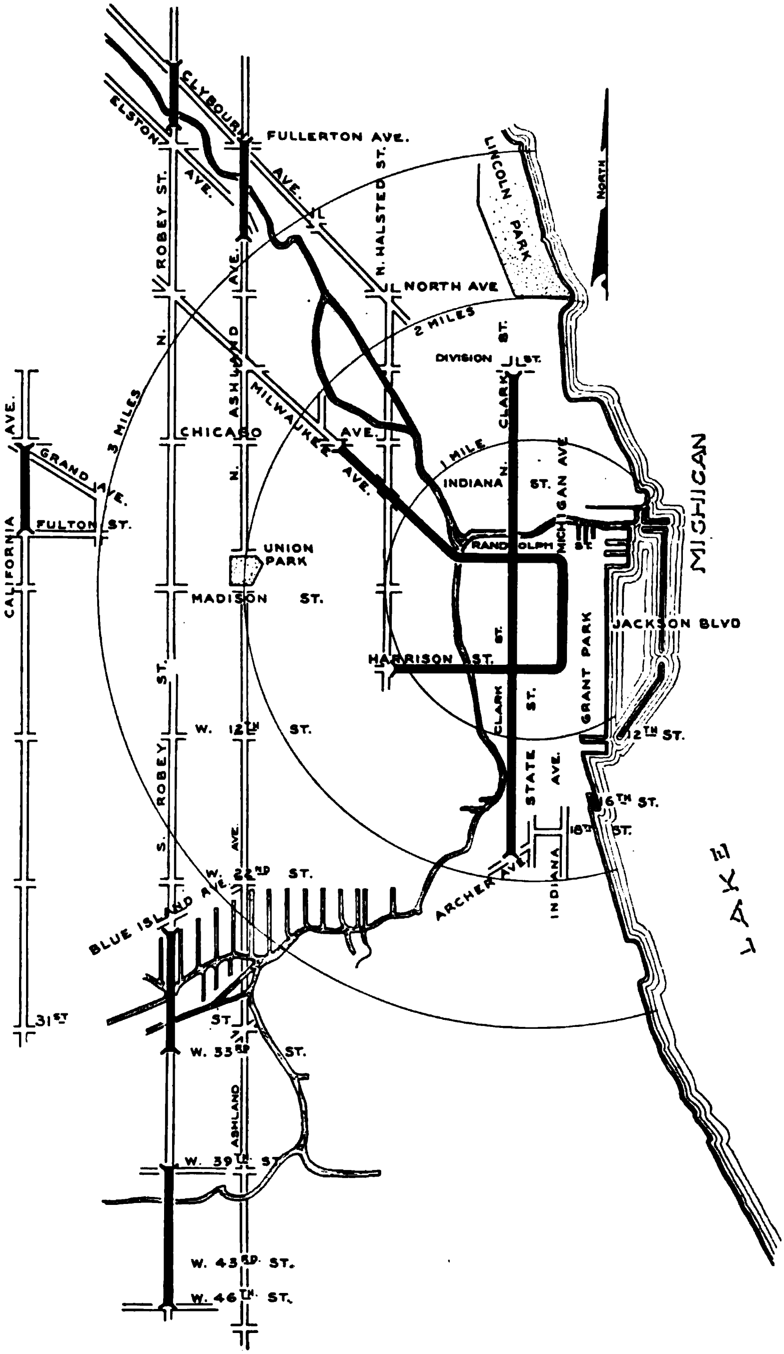


Plate XIII. "Initial Subway" Plan.

to the Board under these ordinances, and therefore in its recommendations it recommended the Clark Street subway as a unit because it is a subway which not only will relieve present surface car line congestion, but will also be able to become finally a part of a comprehensive high-speed system. So we know we are on solid ground regarding that particular street, but I am not necessarily wedded to this street if our restrictions are removed and sufficient money can be found to construct subways on Halsted and State streets simultaneously. When it comes to the loop from the West Side (the U loop as it is called from the Washington Street portal over to Michigan Avenue, back under Jackson Boulevard to Van Buren Street tunnel, and thence out of the portal), that recommendation which the Board made must be considered to be strictly a subway, built for the express and only purpose of relieving surface street car line congestion. I would like to have you clearly understand that we as a Board are limited under the ordinance to the construction of subways which will relieve the surface car lines, and our authority does not extend beyond the surface companies. Consequently, we recommended that U-shape plan for the relief of surface car lines from the west part of the city. Had we been unlimited in our authority, and had we had ample money to construct it with, possibly we might have recommended something like the subway shown on Plate XIII; but being limited as we were to the relief of surface congestion and to the amount of money available in the traction fund, or approximately so, we recommended what we did, namely, under Clark Street and the U loop from Washington Street tunnel, back to the Van Buren Street Tunnel. Since then the sub-committee of the Transportation Committee has seen fit not to adopt this small loop which the Board suggested, which is shown in Plate II. That has been temporarily abandoned by the Council Committee, and instead of it a subway is proposed under Madison Street, running straight west from Michigan Avenue to a point east of Ashland Avenue, possibly as far west as Western Avenue, depending upon whether the Board sees money enough in sight to construct it to that point or not. Consequently, the system of subways now tentatively adopted by the Committee is a straight line north and south under Clark Street, from 19th Street up to about Elm Street, and a straight line subway under Madison Street from Michigan Avenue straight west possibly as far as Western Avenue. That absorbs all the money we now have in the traction fund, namely, the $14,000,000 available at present or in the near future, the additional $10,000,000 or $11,000,000 that will accumulate within the next five years, and $5,000,000 that the city is authorized to call upon the traction companies to pay. A total of $29,000,000, or, say, $30,000,000, is all the money that the Board up to the present time has available to spend, or rather to design subways upon which this money is to be spent.

April, 1914

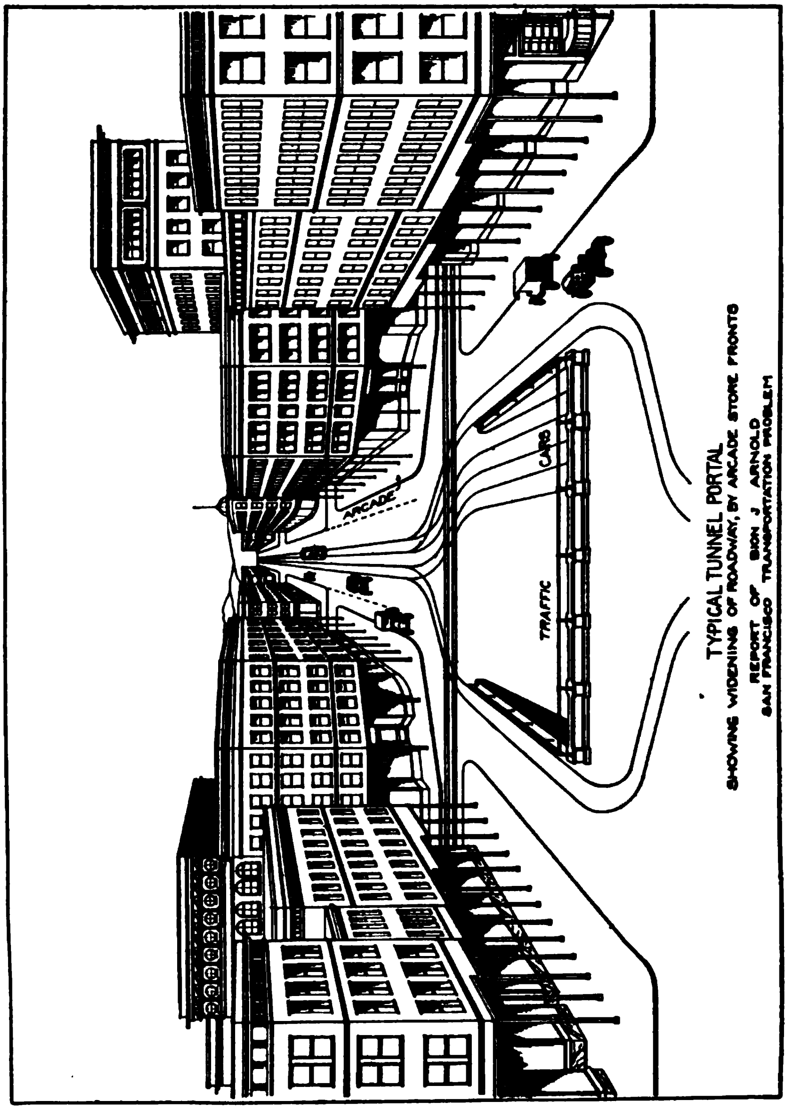
As I said before if we were not limited as to the amount of money, if we had about $50,000,000, we could lay down a subway system for this city which, I think, would come fairly close to satisfying the present demands for subway transportation in the city. I do not want to say definitely tonight that I am of this opinion (because I am not certain as yet), but I am inclined to believe that $50,000,000 is about the limit that we can support upon a very low interest rate by the surface system at the present time, and I am not certain that we can support over $30,000,000. It depends entirely upon what rate of interest the city of Chicago requires the traction companies to pay it in the form of rental upon the money invested in the subway. In other words, if the city demands that the traction companies pay 5% upon such money as the city puts into the subways, then of course we must spend less money. If, on the other hand, the city says, we will allow you to build more subways and only charge you 2% rental or 3% rental, then we can build more subways. The vital question before the city today, before the sub-committee of the Transportation Committee, and finally the Transportation Committee and the City Council, is as to what that rental will be, because upon the amount of rental depends the extent of subways you will get under the proposed "Initial Subway Plan."

Now, if we had $50,000,000 and were free to design, we could take this recommendation we have already made of a line on Clark Street, running straight north to a point near Menomonee Street. On such a plan we could converge many of the Archer Avenue cars, many of the Wentworth Avenue cars, many of the State Street cars, and many of the Cottage Grove Avenue cars into that subway at its southern portal, and run them rapidly to this point near Menomonee Street. Then they would diverge through these two trunk lines to the north, under Lincoln Avenue and North Clark Street, as most of the traffic for the North Side goes over these two lines. From the one portal at 19th Street and the other at Lincoln Avenue we would be able to handle the main trunk surface line cars, run them through the business district rapidly, and get them away rapidly at the southern portal and also at the northern portal. But if we are required to shove that portal back where we have no diverging streets, we will be somewhat handicapped in coupling and uncoupling cars and getting them into the subway. Therefore, that is why I have stated that while the portal is tentatively adopted as Elm Street, there is no certainty it will remain there.

On the West Side lines, if we could discard the small **U** loop and design our Madison Street line straight west,—which, by the way, is the proper location of one of the straight east and west lines if it is to become a part of an eventual comprehensive, high-speed subway system, because it is an absolutely straight street, a wide street, and a business street, or, if we should abandon the idea of spending our money on Madison Street and come back to the loop or U idea (Plate VII) for the West Side at present, we could then have a subway connected with the Lake Street elevated at Sangamon Street, then east under Randolph to Michigan, south under Michigan to Harrison, west under Harrison to Peoria Street, and connecting with the Metropolitan elevated. Inasmuch as the elevated roads are now operated under the same management, they could, of course, through-route in the same way that they do now. Connected with the same subway and for surface car operation temporarily, we could begin in Milwaukee Avenue at about Chicago Avenue (Plate XIII), thence south and east under Milwaukee Avenue and Randolph Street to Michigan Avenue, south under Michigan Avenue, and back under Harrison Street to a portal near Halsted Street, into which would go the surface line cars on the Ogden Avenue line, 12th Street, Blue Island Avenue, etc. All of these lines could then converge into this subway, run on a pair of tracks around through the business district and back to and out Milwaukee Avenue, where they would diverge into Milwaukee, Elston and North Avenues, etc. In that way the surface lines here converge and run through the subway, then diverge fan-shaped, in different directions, and thus serve the city probably in the best manner for some years to come that any subway or surface line or elevated system could serve it, located as these lines are, and with the least amount of investment.

The next step, of course, would be to build a subway under State Street or under Halsted Street, depending upon what the city officials decided at that time, and into that would run, if it were under State Street, some of the elevated cars from the north and south in the same manner I have already shown. At the present time this would be all the subway that we could probably use to advantage, and all that the city could support for some years to come, and would, in my judgment, make a very efficient system. Now, if we can find the difference between $30,000,000 and $50,000,000 and get the rental right we may get such a subway as I have here suggested, unless the ideas of our friends holding different views predominate over these, which is not at all improbable.

To show how these portals can be arranged in the street, I have resurrected a view, Plate XIV, from my San Francisco report. You will notice in this view a portal of what is known as the Filmore Street tunnel. We designed four tunnels for that city, two of which are under construction now. (By the way, when they want a subway in that city, they assess the property owners who will be benefited and build the subway. They do not argue over it for ten years to see where the money is coming from.) In order to bring this subway out in a fairly narrow street, we widen the street by arcading the buildings each side of the portal. This tunnel is built for team travel in addition to street cars. Had it been as narrow as a street car tunnel here would be, it would not have been necessary to widen the street so much. This view is simply


TYPICAL TUNNEL PORTAL
SHOWING WIDENING OF ROADWAY, BY ARCADE STORE FRONTS
REPORT OF BION J. ARNOLD
SAN FRANCISCO TRANSPORTATION PROBLEM
CARS
TRAFFIC
ARCADE

—PERSPECTIVE OF ARCADE STORE FRONTS AND TUNNEL PORTAL

A roadway of only 38′ 9″ at so important a tunnel entrance as Fillmore Street is clearly inadequate for both car and heavy vehicle traffic that must use this tunnel. This drawing shows an effective method of street widening at tunnel entrances with minimum alteration in abutting buildings and without recession of the building frontage. The arcading principle is widely used abroad to overcome just such a defect in street plan as exists here.

Plate XIV.

to show how we can handle those portals, and as the subway extends, the portals can be closed if necessary.

I referred awhile ago to the special designing (Plate XV) necessary to get a double-decked system, meaning by that simply where two subway lines cross each other at right angles, or approximately so, to get such a double-decked system in between the structure of the Chicago Tunnel Company and the surface of the street, the distance from the surface of the street to the top of this structure being but 33 feet. In some instances it is 33 feet, 6 inches. I believe there are some cases where it is practically 34 feet, but the limits are 33 feet in most cases. To get two decks of subway in there and leave sufficient space for the surface car track, to get in a possible underground conduit system in the future, and also to get in cars which are large enough to operate on our elevated roads, has been a serious problem. It has been pretty close work, but the subways have been so designed that either one of these decks will take the elevated cars, my theory being, in which theory the Board, I think, concurs, that any subway designed in this city which is at all likely to become part of a comprehensive system—and that means practically every piece of subway that is designed—should be designed large enough to take large elevated cars, because these elevated cars are probably as large as we will ever operate over our elevated structures (I mean so far as height and width are concerned), or cars on suburban lines which may come in and use some of these subways eventually. Consequently, I think every subway should be large enough to take our present elevated cars, and if it is large enough to take the elevated cars, it will take our present surface cars which are shown in outline here. Note that we have had to do some very close designing of the top structure of the high level subway and make our decks very thin, even carrying the rails through on shallow **I** beams in some instances, and putting footings down outside the structure of the Chicago Tunnel Company's structure to bear the weight of the new structure. While that entails some extra expense, it is not enough to make it prohibitive and, in my judgment the tunnel company can be called upon to stand, if not all the expense, at least a part of it—whatever is just, which can be worked out; and I think it is better for the tunnel company to stand part of that expense and not have its grades interfered with than to be compelled to lower its grades, because I think in this way a given amount of money can be used with even more justice than if the present subways are condemned and the company compelled to lower them as required in the tunnel company's ordinance.

Plate XVI is from the 1911 report, showing the Chicago Tunnel Company's structure in its proper position and of its proper size. You will notice that we have to ride over the top on the subway a little bit. I have not shown the special supports there, because this drawing was not made especially for that purpose, but it is to show the arrangement of the surface line cars and the elevated cars. It shows the passenger station at Jackson Boulevard and State Street, looking north on State Street. That is on the assumption that the State Street subway shall be constructed. You will notice we have public utilities galleries for taking care of all the utilities, thus enabling us to leave the street, when once constructed, undisturbed, instead of allowing the streets to be frequently torn up, as they now are

In my judgment, the utilities galleries questions should be met now, met fairly, and provided for in all streets where subways are constructed.

Plate XVII shows another section at Jackson Boulevard and State Street. In this plan the stairways and escalators are located close to the buildings.

Plate XVIII is made from Plate 3 of my 1902 report, and is to show how I proposed at that time to take care of the utilities, and to meet the criticism that is sometimes brought against the method of putting utilities in galleries. Some men will argue—and sincerely, although they are incorrectly informed, in my judgment—that it is unsafe to put gas pipes in utilities galleries on the theory that gas may leak from those gas pipes and get into these large chambers, these galleries, and finally mix with air in the right proportion to make an explosive mixture. Then a short circuit or a match or anything of that kind may cause an explosion, blowing up the whole street and the whole gallery. That, of course, is possible, and in order to meet that criticism I planned the utilities galleries in 1902 to be under the sidewalks, with the high and low pressure water mains put in the lower part of the gallery in an open chamber, and the gas pipes in the upper part of the gallery, buried in sand, so that if a gas pipe leaked the gas would be diffused in the sand and thus be no more dangerous than it now is when it leaks into the soil in the streets and is diffused through the soil. We never get an explosion in the street itself. It is always in the manhole or where there is not proper ventilation.

All this argument of danger from gas in utilities galleries is fallacious, in my judgment, because utilities galleries, as I understand, are constructed in Europe wherein the gas pipes are located in the open galleries. They have been operating for years and I understand they have never had any difficulty with them. Consequently, we can put all cables, all water pipes, all sewers, all wires and conduits, and so forth, in an open gallery if we choose to do so, thus making it unnecessary to have the sand feature.

Plate XIX is Plate 13 of my 1911 report, and shows a section with a single level subway in a narrow street, with two elevated cars and two surface line cars; it also shows how in a narrow street the utilities could be taken care of; the arrangement of pipes; and the ventilating system for drawing the air down through the hollow columns into the subway and diffusing it up through the buildings. That is merely detail which may or may not be used.

Plate XX is a reproduction of another section of the double-decked scheme in my 1902 report, showing the surface line across the arrangement of utilities galleries, showing the size of the Illinois Tunnel subway as it was proposed at that time to build it, and also showing how deep the subway would have to go down in case it was constructed on those lines. My position was that this subway, instead of being increased in size by enlarging upward, should be enlarged downward; that is, if they were allowed to construct a large subway, they should begin at their top point and go down, which, of course, was a serious proposition, and they decided not to do it; later they decided to leave their subways the same size as the other drawing showed, namely, about seven feet high.

When you remember that in this double-decked plan the top of a low level subway platform is only about 30 feet from the level of the street, you will see how little there is to the argument that these deep subways are difficult for the people, because the subways here are such that the lowest subways are closer to the ground than most of the platforms of the New York subways. There they have used six or seven feet at the top of the street to allow for utilities.

Plate XXI shows a station such as I suggested in my 1911 report for Michigan Avenue. My theory was that Michigan Avenue, which, by the way, has since been widened, was a very wide street for pedestrians, especially in view of the vast amount of automobile traffic that was then and now is on the street. In fact, it has since greatly increased. I thought that if we could provide a gallery or a mezzanine floor there, into which people could go down on the west side of the Avenue to their subway trains, they could also continue right across on that mezzanine floor to Grant Park, or to the Illinois Central R. R. if they chose, thus making it unnecessary to cross the street surface, and safe for women and children and men who want to cross without taking a chance. You will notice that all these subways which I showed you awhile ago on the maps converge under Michigan Avenue and give a general clearing station. There are here shown four elevated line cars and four surface line cars, and by simply going up onto this mezzanine floor, one could get from any elevated train to any other elevated train or from any elevated train to any surface car he chose to board. That, I think, meets one of the questions which was raised, I think by Alderman Long, as to how the plans we were talking about now made it possible for passengers to travel from one line of cars to another, either surface or elevated. This system would make it thoroughly practical and a very easy thing where such stations were arranged.

The above illustrations will help you to understand a little more clearly what I was talking about in my general discussion which I laid down in my 1911 report, which reads as follows:

> "Fundamentally, no subway plan should be adopted involving any system of loops, or other methods of construction, which will prevent the building of a high-speed subway system ultimately covering the entire city, through which high-speed trains could be run, for no extensive subway system can be justified from an investment viewpoint unless it is so designed that ultimately high-speed trains, each having a capacity of not less than 10 of the present elevated cars, could operate through it at times of maximum traffic, as it is only by this method that the cost of operation per car mile of such a system can be brought low enough to justify the heavy investment necessary for long-distance subways, and take care of the high fixed charges necessitated in their construction. This does not mean that, aside from financial reasons, it is not advisable to construct at once enough subway in the business district to relieve the present congestion of surface and elevated cars, but it does mean that the ultimate plan to be kept in mind in analyzing the transportation problem of the City of Chicago should be one that will lead toward securing a transportation system that, no matter how owned, will eventually gather the passengers by means of surface line cars and deliver them to high-speed subway or elevated trains, which, in turn, will bring them to and through the business district to whatever extent it may be expanded, in economically and safely-operated, heavy, high-speed trains, stopping infrequently, in order that high average speed may be made, with the intermediate points between these stops served by the present surface line cars or local elevated or subway cars. In such a system the elevated lines would serve the same purpose as subways for such territory as they occupy, if operated into and through the present and future congested business district in subways. The principles upon which such a subway system should be constructed are as follows:
>
> "First: Through operation from the southern termini to the northern termini, wherever they may be located, and vice versa, upon as straight tracks as practicable, on one or more of the following streets: Michigan Avenue, Wabash Avenue, State Street, Clark Street, Fifth Avenue, Halsted Street, Western Avenue, etc., as the future may demand.
>
> "Second: Similar east and west subways, with the grades separated where they cross the north and south subways, located, to start with, say, on Madison Street, and eventually upon such other east and west streets, north and south of Madison Street, as future conditions may demand, utilizing, however, at once certain of these streets in the present business district for loop terminals for the present West Side sur-

face and elevated cars, but so arranged that the subways so used may finally be used for future subway cars.

"Third: These north and south and east and west subways eventually to be supplemented by diagonal subways upon Milwaukee Avenue, Blue Island Avenue, Archer Avenue, and such other diagonal streets as the future may determine best to locate subways upon.

"Since the city extends in three directions only, it is necessary to return to the West Side some of the cars coming from that side, by reversing their direction, either by means of stub-end or loop terminals. This is accomplished in the plan under consideration by loop terminals in preference to stub-end terminals, for by the loop method continuous operation is permitted with the corresponding increased capacity and speed, and the elimination of danger in operation.

"The east and west subways (with the exception of the one on Randolph Street, which must run at high level east of the south branch of the river in order to allow the north and south subways to pass under the river at grades not exceeding those of the West Side subways), after once having descended to come under the river, should remain down and pass under the north and south subways in the present business district, although west of the south branch of the river the east and west subways could be constructed as high level subways, but dipping to allow the Halsted Street and Western Avenue subways, or such other north and south subways as may be constructed upon the West Side prior to the construction of the east and west subways, to pass over them. In case the east and west subways on the West Side of the river are constructed first, the north and south subways should dip at intersecting points.

"In such a system no particular business district would be given any permanent advantage, or any advantage which the natural expansion of the system would not rectify, over any other business district, for the present business district, and ultimately the entire city, would be gridironed with subways, located at approximately equal distances apart, north and south, and east and west, varying somewhat with the density of population, intersecting each other at right angles, except where the diagonal subways were constructed, and thus not only tend to extend the present business district north, south and west, by the elimination of loops, except for the terminals of the West Side system, but also make it possible for passengers to go upon high-speed trains, operated upon straight and practically level tracks, without grade crossings or switches, from any point in the city to almost any other point in the city with but one transfer, and in most cases without transferring at all. Such a system can be constructed and operated more economically and involves less risk in operation than any other subway

> system suitable for Chicago conditions, and it, therefore, possesses the elements, so far as a subway system can, by keeping the investment for good construction to a minimum, of enabling the city to retain its present one-city-one-fare system, whatever that fare may be, and at the same time makes it possible to adopt the universal transfer system, without injustice to anyone, within the district between 12th Street, Halsted Street and the Chicago river, within which district the present surface companies are now exempt by ordinance from issuing universal transfers until the construction and operation of subways.
>
> "By this system all West Side passengers can be carried, without transferring, directly to the Lake Front, if desired, or, by transferring once, to any north or south point of the city served by the subway system."

Those are the principles which it seems to me should govern any system laid down in the city of Chicago. Therefore, the fundamental question which we must meet in the near future probably is, where will we locate those subways?

I have given you, I think, an idea of what the Board thinks and what some of us as individual members think should be worked out. The next question is how the scheme shall be financed—whether it is wise to construct only so rapidly as we can with the money we have available (I mean construct at present with the money we have available), and then extend as rapidly as we can with the money which comes in from the traction companies, which is coming in at the rate of $2,500,000 per year at the present time, and probably will increase to $3,000,000 in the near future, so that in five or six years from now we ought to have from $25,000,000 to $30,000,000 available for subway construction. Shall we use that money, build now with what we have and extend as rapidly as we can, or shall we find some means of obtaining additional money, and instead of building $30,000,000 worth of subways now, build $50,000,000 worth? That question, of course, I am not at liberty to say much about. It is in the hands of the City Council, and is a very live subject.

The question of congestion is the fundamental thing to take care of at the present time. Therefore, we as members of the Board have said that our subways should be constructed where they will relieve congestion. I think, for the best interests of the city of Chicago as a whole (looking at the matter from the viewpoint simply of a citizen who would like to live a hundred years, if possible, to see what the city would be at that time, which I have not any chance of doing, but at the same time I believe people should think about the welfare of the city at that time), I would probably put the first subway under Halsted Street, north and south, if I had absolute authority. Of course, my State Street friends wouldn't love me a bit for locating the subway over there.

On the contrary, if I located the subway on State Street, my Halsted Street friends would not think any too much of me. So the Board has concluded that Clark Street is a pretty fair compromise between the two north and south arteries, and that it is a good place to start, especially as it can become part of the comprehensive scheme.

The outlying territory needs to be developed. The question is, will you develop it with subway, elevated, or surface lines? The cheapest way is surface lines, then elevated, and then subway. As our city is so spread out, fan-shaped, that we cannot afford subway systems throughout, not having people enough in the outlying territory to support them, it is not the part of wisdom to talk about building a comprehensive subway system, covering the entire city right from the start and being able to support it. If we were to construct such a subway system and get it running three years from now, or five years from now, which would cost, say, $130,000,000, we would have to immediately increase our riding habit 20% in order to support that system. We cannot increase our riding habit 20% at once. The question is, how long will it take us to increase 20%? Our theory is that it would be better to build with the money we have, be able to support our subway now, and then add in the future as our conditions warrant and as we find we can support it.

The only other step would be to grant a franchise upon some basis for a very long period, which would provide for an amortization fund at very low rate, so that in the course of time the earnings of the system would amortize the investment. But in my judgment that franchise would have to be not less than 40 years, and possibly 75 years, and I do not imagine I will see the aldermen voting for a 75-year franchise right away, although it is, of course, possible. I doubt it, however.

While the through-routing on the elevated roads which has recently been put into effect has given more or less trouble, the trouble is due to the fact that we are not yet quite used to it; the patrons of the elevated roads are not yet used to getting off and on and transferring quickly and at the right points, and, furthermore, there are not quite enough transfer points. When those things are worked out, I am sure you will like the through-route systems. We have been asking for through-routing on the surface lines for years; we have it somewhat in vogue, and expect to have it fully in vogue in a few weeks. This through-routing of the elevated roads will give only temporary relief. Our present surface line traffic, street car traffic, has responded very rapidly to the rehabilitation of the system, and we have increased the average speed from seven miles per hour to about nine miles per hour. In Vienna the average speed, I understand, is only about seven miles per hour. This increase of speed on the surface lines to nine miles per hour has greatly increased their receipts and has correspondingly hurt the elevated traffic. Consequently, the elevated companies are studying the problem now of how they can increase their service to get that traffic back. It is a merry war between the two to see who will get the fluctuating riders. The traffic has increased at the rate of about 5½% per year. That is, the traffic on the surface lines will double in from 13 to 15 years. You can see what we are facing if we do not provide additional facilities for taking care of the travel. We cannot take care of it on the surface of the streets in our downtown district, because we have no more streets upon which we can put street car tracks. We have either to provide more streets, put the tracks overhead on elevated structures, or under the ground in subways, if the business district remains as it is. The first thing to do is to lengthen this business district, extend it north, south and west, which additional streets and tracks are bound to do. Still, there are many people who will want to come into this downtown district, and unless we provide additional streets or tracks in subways or on elevated structures, we will be swamped before long. In fact, we are pretty well swamped already.

Now, Chicago, as I have said, is so designed or so located that it is impossible to get sufficient density of traffic over such a number of subway lines as would be necessary to support those subway lines if we now put, say, $130,000,000 or $140,000,000 into them. Consequently, we can only build subways where they are needed to relieve congestion or where we are sure there is or soon will be traffic enough to support them. I want to say now, so nobody will misunderstand me, that a subway is not an economical proposition and not a fundamentally sound proposition for surface car line operation. You cannot put surface cars enough into a subway to make it pay from that standpoint if they are operated singly. The only excuse for putting a short subway down town, or at any other point, is to relieve congestion. I would like that thoroughly understood. At least that is my viewpoint.

As I said a few minutes ago, a subway can be defended only from an economical standpoint when it is built so as to run high-speed, say, 10-car trains in it, at frequent intervals; because only by that means can you carry passengers enough on a five-cent fare to justify the investment in the subway. Hence the two viewpoints. You must build them for that purpose, or else you must build them simply to take care of congestion because of the fact that you are congested and cannot find any other place for the tracks. That is just the situation in the downtown district today, and that is why the Board advised the building of a new loop for the West Side cars, not because they thought it would pay, but because we had no more tracks to run cars on, and we were limited to the 1907 ordinance provisions. When we talk about subways to be built today, we should mean that we are talking about high-speed subways of the future. Every subway that we are designing now, as far as we can, we are so designing as to make it part of a comprehensive system. Now, we are not building them necessarily because they will pay for so doing, but to relieve congestion. We will use them temporarily to relieve congestion, and finally they will be made part of a comprehensive subway system that will pay when the city is more densely populated.

DISCUSSION.

R. F. Schuchardt, M. W. S. E. (Chairman): Of the many important problems before modern cities,—not only American cities but cities all over the world,—problems of housing, of cleansing, of transportation, the problem of transportation is by far the most important, in that all the others depend upon it. Chicago has had to face that problem many times. We started in our system of transportation with a lot of small systems, and then tried to patch them together. We had a gigantic task to get them in decent shape. There have been many problems since then which we have had to meet.

If there is any one man of this city who is pre-eminently an expert on this subject and who has given it tremendous study, it is Mr. B. J. Arnold, who needs no introduction to a Chicago audience. We are very happy to have had the pleasure of listening to him this evening. His very clear description of the essence of the problem has undoubtedly banished from any mind the confusion naturally resulting from the description and arguments with which we have been entertained during the last few months. It is natural that upon a subject of this kind there should be many differences of opinion, and those differences of opinion, I hope, will result in a lively discussion here tonight. There are many men here, I am sure, who have given this matter considerable study, at least some of the angles of it, and I hope they will feel free to take the floor and give us the benefit of their viewpoint.

M. M. Fowler, M. W. S. E.: I would like to ask how this plan fits in with the Chicago Plan. The Chicago Plan, as I understand it, is to bring most of the railroad terminals down near 12th Street, and that will bring a good deal of the railway traffic very close to 12th Street. Should not the subway now shown near Van Buren or Harrison Street be located a little further south?

The Author: I am glad the gentleman asked that question, because it reminds me that I neglected to speak about the railway terminal question, so I can make another long speech if you want it.

Plate XXII shows the present business district, and the property occupied by the railroad companies. That part of the map shown cross-hatched is railroad property, and the little cross-hatched portions shown at the top just left of the center represents the property that the Pennsylvania Railroad Company purchased for the purpose of constructing freight terminals. Taking the cross-hatched portions, we can see how much property is occupied in our downtown districts by the railroads by right of ownership. You will notice how restricted we are right in the vicinity of 12th Street, as the gentleman has said. We have but three streets left there upon which we can bring street cars northward to our present business district. I have recently had something to do with this railroad problem and have given it some study, and one of my recommendations—in fact, the fundamental thing that I thought should be done, was to straighten the river from some point, namely, from about Harrison Street south, so that all of that property now located between the present river and the proposed straightened river would be transferred from the west side of the river to the east side of the river. Plates XXIII, XXIV, XXV and XXVI show different locations for straightening the river suggested by me in my recent report upon railroad terminals to the Citizens' Terminal Plan Committee. If the location shown on Plate XXV should be adopted, and figuring the property as worth $5.00 more per square foot when thus transferred than it was before, which is a very low estimate, some people figuring it at $10.00, there would be added to the value of the property some $16,000,000, or nearly two and one-half times the cost of straightening the river, estimated at about $6,000,000.

Of course, to be perfectly fair about it, that increased value is on the assumption that this property could be intensively developed, utilized for both railroad and commercial purposes, and be made to earn a return similar to what other property contiguous to it or in the vicinity of it now earns; but when you consider it as purely railroad property, used purely for railroad purposes, then the differences in value are not so great, because, presumably, the property would not be worth very much more for switching yards and sand piles, as it is now used, on the east side of the river than it is on the west side. But when properly used, the question as to how much that value is depends upon each man's opinion as to how he would use the property.

The fundamental thing to me is that the companies should find some way of intensively developing their railroad properties in this extremely valuable district, so as to get a revenue from that property over and above what they get from it as purely railroad yards. Our railroads are now taxed upon a basis of $40,000 per mile of track instead of the real value of their property in the city limits.

But some day that will be readjusted. When that time comes I think you will find the railroad men developing this property more intensively than they are now developing it, and the property will be considered much more valuable. If you figure it on the ten-dollar basis, this amounts to $32,000,000, but I am not assuming the responsibility for that figure. It is probably too high. However, it is reasonably safe to assume that there is an increase of $16,000,000.* If the river were straightened out, it would open up this great business district to the south, if these railroad companies would depress their tracks in that district and develop their property. That, in my judgment, would make it impractical or inadvisable to attempt to put a system of railroad stations across 12th Street, as the gentleman has stated the Chicago Plan Commission thinks it wants to do. I am not so sure that the Commission wants to do that at all, but it does, in my judgment, want to do something that will open up this business district to the south in the same manner I have indicated, and it is not wedded at all to the idea of having a row of railroad stations across 12th Street, which would practically cut off the business district instead of opening it up. What the Chicago Plan Commission tried to do was to design two railroad terminals at that point, such as all the roads could use, and thus open up this district to a certain extent; but they are not against, in my judgment, any other plan which will completely open up that business district.

---

*The ordinance passed by the Chicago City Council on Nov. 13, 1913, provided for the straightening of the river as shown by the cross-hatched portions on Plates XXIII and XXV, very close to the location recommended by Mr. Arnold on these plans.

Coming now to the station question: If this city could find its way clear to so negotiate with the railroads as to get the railroads persuaded to construct two passenger stations, we will say, one on the present Illinois Central R. R. Company's site (which, by the way, is quite likely to be developed—in fact, that company is now moving toward that direction, that is, it is designing a new station and will undoubtedly build a new and very handsome station at this point), Plate XXVII, and another station located at some point anywhere between Madison Street and 20th Street, west of the river, we would then have two stations, which, if each were large enough, would be ample to take care of this city for some 50 or 75 years to come at any rate, provided those stations were planned to take care of through traffic only. I mean by that, main line traffic, and the suburban traffic handled in smaller stations in the same manner that the Illinois Central now handles its traffic along the Lake Front. If the roads operating on the West Side had a terminal at Adams Street, or Harrison Street, or at 12th Street, if you choose, the whole district from 12th Street to the river could be completely opened up, and there would be no line of stations across 12th Street, as the gentleman has assumed the Chicago Plan Commission desires.

The North Western station being built, and the Illinois Central station being fairly certain, the Pennsylvania group of railroads comes in and desires to build a station. My conclusion was that the North Western is a permanent station and, therefore, some other location would have to be found for the Pennsylvania Company, and that it was entitled to a location somewhere near the business district; that it was not just to the Pennsylvania Company to require it to back clear up to 12th Street, as some have demanded of it, and, therefore, Harrison Street would be a fair compromise location for that company, if it would accept this site. The city is desirous of getting the Lake Shore and Rock Island station moved back to 12th Street or some other point. If the

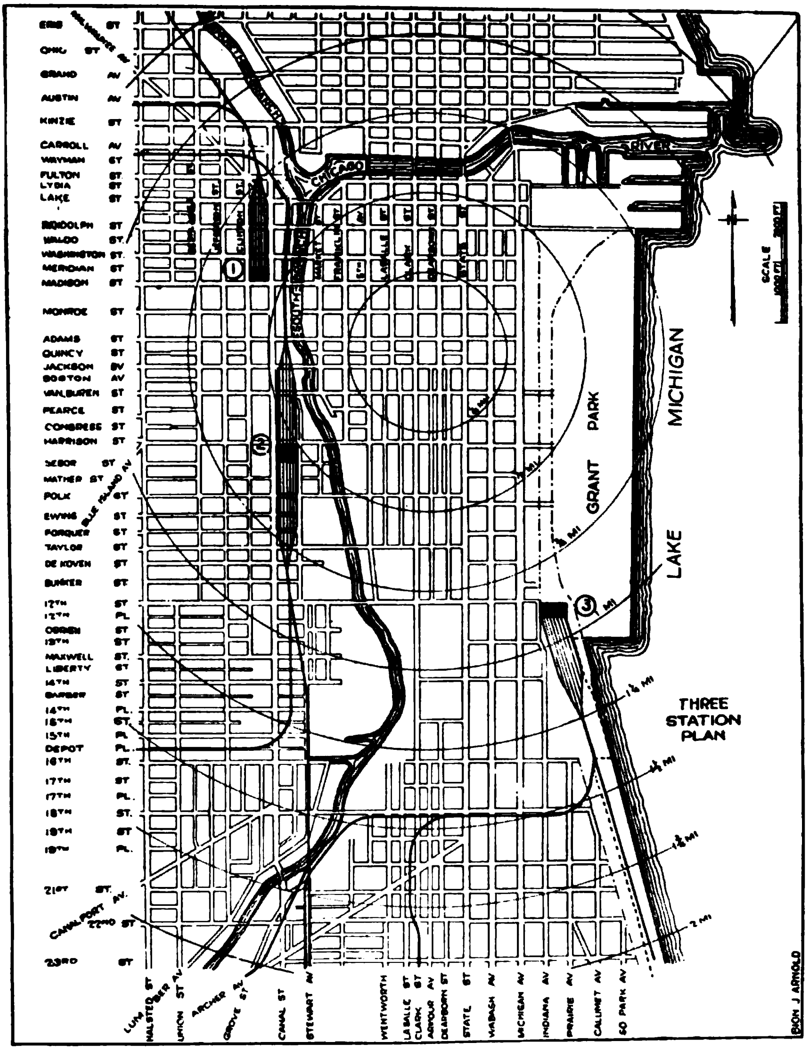


PLATE 27. THREE-STATION PLAN.

This plan contemplates three terminals, the first being the present Chicago & North Western Station, the second being located at Harrison Street, between Canal Street and the river, and the third being located at 12th Street and the lake front. This plan permits great expansion of the business district. With proper grouping of the railroads many of the railroad and river crossings would be eliminated, and the street system would be greatly improved.

Streets and river shown as now existing.

Pennsylvania and its associated roads would build at Harrison Street, we would then have some sort of a lever upon or a means to coax the Lake Shore and the Rock Island roads and other roads to move back or go into the Pennsylvania station, or into the 12th Street station of the Illinois Central R. R., and thus open this at present congested throat to the south. There is nothing in the principle which I am advocating for the location of passenger stations to oppose the construction of a station at Adams Street. As far as the principle I am talking about is concerned, it makes no difference whether the Pennsylvania and its associated roads build at Adams Street, Harrison Street, Polk Street, 12th Street, 22nd Street, or anywhere they choose, as long as they will keep along that north and south line and not put any station between Michigan Avenue and the river, my object being to keep the business district open to the south. If they would construct their station either at Adams Street or Harrison Street and use it for through traffic, the C., B. & Q. and the P., F. W. & C. railroads could come in from the south, and the Panhandle and the C., M. & St. P. Ry. from the north. Let me get this clearly before you. I say that fundamentally there should be two passenger stations for the city of Chicago, one on the Lake Front, and one on the territory west of the river, which is natural railroad territory, being not only low, but already crossed by viaducts in many places. It has been agreed by the companies that if they do occupy it—I mean it is tentatively agreed—they will depress to within three or four feet of city datum, which is within three or four feet of the water line. The Illinois Central R. R. has agreed to depress its tracks, and therefore we would have space on each side of our business district in which could be constructed any number of stations—farther north, farther south,—paralleling our business district, and at the same time not closing it in either on the north or the south.

Plate XXVIII shows the development of the suburban arrangement. I claim that if these railroads would take care of their through main line traffic, their main passenger trains, New York to Chicago, Chicago to the coast, Chicago to Minneapolis, Chicago to St. Louis, and so forth, in their regular stations, designed especially for that work, which may be stub-end stations if you choose or through stations, there being no great difference in their capacity if they are properly designed—if they will take care of that class of traffic in monumental stations designed for that purpose, if they must have them, then there should be no criticism due. But when they design great monumental buildings and fill them full of suburban tracks which are used a short period of the day, morning and evening, and stand idle the rest of the day, I claim that is a waste of money for terminal purposes. This suburban business can be taken care of better in more and cheaper, yet sufficiently handsome, structures which at the same time will better accommodate both the roads and the public than these monumental terminals, which should be designed especially for main line business.

If the Illinois Central Company were to retain its stations at 12th Street, Van Buren Street, and Randolph Street, as it now has them, then run a subway under the river and swing west on Ontario Street and establish a station at State Street and another one at Franklin Street, thence run west and north and connect with the tracks of the North Western and the Milwaukee roads, the Illinois Central suburban trains would serve this entire business district, as they now do on the east, at the different points, 39th, 22nd, 16th, Van Buren, Randolph, State, LaSalle, and so forth, and out on to the North Western. In like manner some of the North Western and Milwaukee trains could run over the Illinois Central tracks to the south, and also could run trains down to their present terminals or through the Canal Street terminal, if you choose, down to 12th Street, on down to 22nd Street and to the south. The Pennsylvania, the North Western, and the Milwaukee roads could through-route over that division west of the present business district.

Now take the Lake Shore station, located at Van Buren and LaSalle Streets. If we can get the railroads to depress and cover their tracks in the business district north of 12th Street—and it is quite likely we can—then this LaSalle Street station could be retained as a suburban station, and another station could be established at 12th Street, so the Lake Shore, the Rock Island, the C. & E. I., and other roads from the south could run their suburban trains on these covered tracks up through LaSalle Street, through the present street-car tunnel in LaSalle Street, and thence north to a connection with the tracks in Ontario Street, as above described. By reversing the direction we have a through line of suburban cars running north and south through the business center, and at the same time have not blocked the business district north or south by any series of stations across 12th Street or by stub-stations at any point. The C., B. & Q. trains could run in from the west as far as the river, thence north through suburban stations at 12th Street, the new Union Station, and then west on the Milwaukee or the North Western tracks to Norwood Park or West Chicago. These routes are shown on Plate XXIX. That could be worked out in almost any way desired. I believe that will answer the question as to blocking 12th Street.

I simply want to show by these plates that the plan is capable of being worked out if we can get the railroad men to make up their minds to do it. The railroad men very naturally say, "We do not want this suburban business. We are tired of it. It is the kind of business we do not want. Consequently we should not be forced to take on any more of it. My answer to that is, that it seems to be a question as to whether the railroads are going to run the public or whether the public is going to run the railroads, or, better still, whether we can come to an understanding. It is going to be a battle. We do not know yet how it is coming out, but if the public demands of the railroads that their rights-of-way be used to their maximum capacity, and that part of that capacity be used to carry suburban people, then the best way to carry people to the best advantage of the people and at the same time the most profitable to the railroads, is by the through-routing plan.

Plate XXX is a view of the city of Pittsburg. They through route there and yet come here to Chicago and say it cannot be done. No, they do not say it cannot be done; they say they do not want to do it. That is better.

If I have answered the question I will stop.

James Lyman, M. W. S. E.: I am sure I express the sentiments of all here tonight when I say Mr. Arnold's address has been of unusual interest. He has presented a solution for the railway terminal question which not only meets the needs of the city, but presents no serious financial hardships to the railroads. The enhanced values of the railway vacant property by the straightening of the river will in a large measure pay for the street viaducts and modern freight warehouses.

He has offered a solution for rapid transit city and suburban passenger service that would meet the present and the future needs of Chicago for a long time to come. If this scheme were adopted and the terminals and suburban service electrified, the increase in transportation which always follows electrification would soon pay a good return on the new investment.

I would recommend to those who have not seen Mr. Arnold's report on "The Rearrangement and Development of Railway Terminals," of November, 1913, that they obtain a copy from the city and read it.

F. E. Davidson, M. W. S. E.: I want to ask Mr. Arnold why the Board determined on a two-track subway instead of a four-track subway, and I would also ask in how many years a two-track subway will be absolutely inadequate to handle the transportation which you propose to put in the subway, assuming the increase which you have.

The Author: The subway will be inadequate before we finish it. We figured on two tracks because we did not have any more money. If we had had more money we would have figured on four tracks, and probably located them elsewhere. But we have not yet the money to construct those two additional tracks under Clark Street. That is why I put in here now a tentative and very indefinite discussion about the $50,000,000. I do not know that we can get $50,000,000, but I think we can get $30,000,000. I do not know that we can support $50,000,000 if we do get it, so I want to leave the question of how we would spend it somewhat up in the air until we get a little further along with the negotiations.

You understand that I am not now trying to define a policy for the City Council. I am not trying to tell the City Council, in a public speech before an engineering body, what it ought to do, because I must leave questions now under discussion by the Council

Committee, and which the Council properly has to settle, to the City Council. So I must at present talk a little vaguely about the money we can spend, until the members of the Council make up their minds how much they will let us spend, and how much rental they want upon the expenditure. If they do give us $50,000,000 to start with, then we can build a double-tracked subway in Clark Street, or possibly construct a four-track subway somewhere else, but it now seems to me well, with the money available, to build the two-track subway for the relief of surface car line congestion, leaving it so that four tracks could be put in later, or utilize the money for the construction of four-track subways on other streets. Does that answer your question, Mr. Davidson?

Mr. Davidson: Yes, it answers my question, but from the standpoint of the engineer, would it not be well to recommend what the Board knows would be best for the city of Chicago, with the idea of educating the people to the idea of spending the money which we know must be necessary in a short time?

The Author: That depends upon the conditions under which a man is working, and you will find that I will do so before the subway question is finally settled by the Council. I agree with you, and you remember the principles I read from my 1911 report, but at the same time I have to meet these conditions as they come, and not take an impossible position. I always aim to get results. If I cannot get everything right on the start, I get as much as I can, provided I do not spoil the situation for getting more at a future time. That is the theory on which I am going.

Mr. Schuchardt: Mr. Lyman's remarks regarding electrification prompts me to say that we had hoped to have with us this evening Dean Goss, the Chief Engineer of the Committee of Commerce on Electrification and Smoke Abatement, but I regret that he is not present. We have waited patiently for this long-deferred report, but we are given to hope now that it will come out very soon, and we think it will probably show that electrification is entirely feasible. With that mooted question settled, the rest will probably be easy.

One of the Citizens' engineer members who has followed the subject with a great deal of interest is Mr. Bement. I am sure he can tell us something that is interesting.

A. Bement: The author has made the matter so clear that anything I might say would not add any information.

The Author: I want to say that Mr. Bement did add a good deal of information to the general railway terminal question at the time I was analyzing it. I know he knows a great deal about it, and he was of great assistance to me by voluntarily contributing information at the time of the compilation of my report. I want to say that much for him, if he will not talk now, as he deserves it.

Mr. Schuchardt: Mr. Lake has had considerable experience in transportation problems, especially structures and power problems. May we not hear from him?

E. N. Lake, M. W. S. E.: Since you have given me the opportunity, while I had not expected to say anything, there are one or two thoughts which I might add. In looking over some old records, I ran across this rule applying to steam road operation of not so very many years ago. I cannot repeat the exact wording of the rule, but this is the substance of it: In the event of trains meeting between turnouts, that train which is nearest to the turnout shall back up. When trains meet, the conductors shall immediately get together and determine which trains shall back up to the turnout. It was especially mentioned that due consideration should be given to grades and the respective loads of the meeting trains.

Now, this seems very strange to us of today, but perhaps the investigator of the future will find, when he runs across some of the illustrations that were shown tonight, some things which will seem to him equally strange. I refer particularly to the view showing the present loop operation and so-called "switchbacks" in the downtown district, and to the view showing the use which is being made of railroad property in the business section. Those views will in the not very distant future seem as strange as do the old-time train rules.

Boston, I believe, enjoys the distinction of having more different kinds of subways than almost any other city in this country. At certain places you go down into the subway to get the elevated trains, and at others you go up on the elevated structure to get the subway trains. Boston has tried all kinds of subways. The surface subway for the purpose of relieving congestion, and the subway for elevated traffic. One of the most recent and most successful is a purely rapid transit subway built from a point in the downtown section to Harvard Square. The Harvard boys say it is now only "seven minutes to a drink," whereas previously they had to travel about thirty-five minutes.

One point I wish to bring out in connection with this rapid transit subway is the advantage of the long trains, the high speed service, and the rapid loading features of the three-door cars which are being used. It was my privilege, when the subway was first opened, to see the way in which they handled one of those tremendous football crowds,—forty or fifty thousand people literally dropped on the transportation system in the space of a very few minutes. The way those eight and ten car trains, with their twenty-four and thirty doors to a side, melted the crowds on the subway platforms as fast as they accumulated, was a marvel to behold.

To put that speed in terms of Chicago distances, I would say that the seven-minutes running time between Park Street and Harvard Square corresponds to about the distance and time from State and Madison Streets to Douglas Park on the west, to the north end of Lincoln Park on the north, and to the Douglas Monument on the south.

Mr. Federman: I am an outsider, but would like to ask a question. I am always interested in the economic side of a subject.

The question that occurs to me is whether it is feasible and just to build subways by special assessment, or, for instance, to move the river as was mentioned, by special assessment? I refer, of course, to the assessment being levied on the owners of the land that is benefited.

The Author: Yes, I think it is just to assess property for the benefit of an improvement, especially in the case of a subway. I mentioned in my talk that San Francisco is building two tunnels under just such a method, and I firmly believe that if we were to start right out on that theory today we might get a comprehensive subway system for this city which would give us much better rapid transit than we can hope to get under any present conditions. I do not know whether anyone has the "nerve" to start it or not. In talking before the Real Estate Board the other day I forgot that point entirely, owing to speaking without notes, although I intended to talk about it. It would not be popular, but I thought they ought to know what I thought. In other words, there are very few situations in any city in this country which will justify the construction of a subway from a financial standpoint,—which will give it traffic enough to warrant its construction and support it; that is, take care of fixed charges, operating expenses, including maintenance and depreciation, and possibly a low amortization fund.

There are conditions that arise where we have to construct subways whether they will support themselves or not. That condition arose in Boston, as Mr. Lake brought out, to relieve the surface lines. They dip the elevated trains and surface line cars under ground through the Boston Common; then they changed their method of operation, and concluded they would put another subway down just east on Washington Street. They then decided they would build over to East Boston, and they have built a subway there. They learned some more. We all learn as we go along. It is no reflection on anybody. Then they built the last one, which is the one from the Common to Harvard Square in Cambridge, where they are "seven minutes to a drink," as Mr. Lake said, and, of course, with this advantage and being the latest it is the best subway built. It is just a rapid transit subway, built under the conditions that we would like to have for every subway, namely, where the traffic will support it. This being practically between the greatest suburb of Boston and Boston proper, the suburb is so large and Boston so large that there is traffic enough between them to keep that subway running, perhaps not to its full capacity, but to a sufficient capacity to warrant its construction from a financial standpoint.

Now then, if we cannot give subways, as a general proposition, business enough to support them, how can we get them? The fundamentally just way to get them in outlying districts where they cannot support themselves is to assess the property benefited by them. To show you what that means, take the Interborough Subway in New York. That is the first one built in New York, and runs from New York to Harlem and up into the Bronx. The rise in the value of real estate above 125th Street along that subway within, I think, five years after the subway was constructed, over and above the average rise that the property would have had, taking the last ten years preceding the construction of the subway as a basis, was such to the abutting property owners (that is, the property owners along the subway right-of-way, within a couple of blocks) as to be sufficient to more than pay the entire cost of the subway. The subway cost $75,000,000. The rise in value of that real estate was something over $80,000,000. That is what it means, and that is the benefit the real estate owners received and they should have paid the cost of the subway up into that district. Of course, New York is a specially constructed city, you might say, a long narrow city, and the congestion is very great, and consequently it supported the subway from the start, although just barely so for some years. There was a field for it. But had there been no one up in Harlem—and there were not so many there in the district I speak of—it would have been perfectly right to assess the property owners for the extension of the subway in that district.

I am not certain whether that method is being used now on some of the Brooklyn subways or not. I advocated it there before the Public Service Commission. There was quite a discussion on it and it was quite seriously considered. I will not say it is in vogue, because I am not sure it is, but I have a hazy idea that there is something of that kind in connection with one or more of those Brooklyn extensions of the tri-borough subway. I will not make the statement positively until I check it up. But the method is in vogue in San Francisco and is being applied to two subways or tunnels I designed and recommended the construction of in that city,—one on Stockton Street, a short one, and the Twin Peaks tunnel, a little over two miles long. They are constructing that subway under the Twin Peaks, and thus opening up a great suburban district which is now inaccessible to San Francisco and they are assessing the property benefited for the entire cost of the subway. That is the law there, They are in advance of us. If we had such a law here, we could have a comprehensive subway in a little while. The property owners would feel very sorry until it began to operate, but they would be very happy after awhile when they began to get their assessments back due to the rise in the value of their real estate. It would be a very unpopular thing, however, for an alderman or other candidate for office to advocate before an election.

G. C. D. Lenth, M. W. S. E.: In connection with the question of taxing the property benefited for the building of subways, it occurs to me that there is a clause in the Illinois Statutes on Local Improvements which might cover the very point the author brings out.

Any improvement can be constructed under the Local Improvements Act provided that it "enhances the value of the adjacent property as distinguished from benefits diffused by it throughout the municipality." The courts have held that "the fact that there may be some benefit to the public from a given improvement does not prove that the improvement is not a local improvement." It certainly appears to me, in view of the above language of the Supreme Court of the State of Illinois, that a subway could and should be built by special assessment. The possibility of subway construction is further specifically mentioned in Section 42 of the Act, a part of which is as follows: "It shall be lawful to provide by ordinance for any local improvement * * * * that the aggregate amount assessed and each individual assessment * * * * be divided into installments not more than ten (10) in number; provided, however, that any such special assessment for the building of sewers, *subways* * * * * may in like manner be divided into not exceeding twenty (20) installments."

The Author: I hope you are right.

F. G. Vent, M. W. S. E.: I would like to know the author's view on the proposed taking care of transportation by elevated roads. We all know that the loop we have now is not properly constructed. It has been put in with the roads crossing each other; and the through routing north and south would be all right, to a certain extent, yet we should consider the north and south trains that are blocked by the east and west trains at the crossing points. Suppose the loop were extended and double decked, and suppose it were made of Maairi steel so that less light would be shut off; has that question been considered yet? Another thing: Would the developing of transportation by elevated structures increase property values as much as the subway would?

The Author: I have given a great deal of attention to the question of the rearrangement of the elevated loop, also the question of the construction of such a loop of different material, although not with the exact view in mind that the member asked about.

In 1905 I made a report to the Transportation Committee of the Chicago City Council upon the subject of "Increasing the Capacity and Reducing the Noise of the Union Elevated Railroad," known as the Loop Elevated, and in that report I showed methods of through-routing trains on the elevated loop which are partially in effect today, although I do not think the plan that was adopted is quite as good as the one I recommended, because I do not think there would be the congestion there is now if all of the recommendations of my report had been followed. However, the elevated engineers are here and they presumably know better than I do. I know they have not tried my scheme yet, so I am free. Plate XXXI shows the method of routing I recommended.

In that report I recommended that the elevated structure be double-decked at the corner of Lake Street and Fifth Avenue, and at the corner of Van Buren Street and Fifth Avenue, so that the Northwestern trains would come straight through down the Fifth Avenue side and thence east on Van Buren Street, and thence south on the South Side elevated. The South Side trains would come north on the Wabash Avenue side, thence west on Lake Street and thence north on the Northwestern. The inside tracks of the loop would be elevated over the outside tracks at Lake Street and Fifth Avenue, and the outside tracks would be elevated over the inside tracks at Fifth Avenue and Van Buren Street. The Metropolitan and the Lake Street cars were to loop. The Northwestern and the South Side cars were to run through as they now do, but I had the cars on the two tracks running in opposite directions on the loop, which in my judgment would be more convenient for the people than the present arrangement. I did not have a single grade crossing on the loop. I thus eliminated completely the congestion then due and now due to the intersections. Of course, some objection was made to the double-deck structures in the streets. We cannot advocate anything that there is no objection to, and those who talk the loudest sometimes defeat the best thing, although they may not have as full information as some others.

But that is what I recommended at that time. If you eliminate the intersecting points by elevating the tracks, you have practically two double-tracked railroads, one running from north to south and the other from east to west, and that arrangement gives maximum capacity. Under this plan, if all trains were through-routed and the station platforms extended, I showed that the increased capacity would be about 100% more than the method of independent-loop operation then in use would give.

At the same time I advocated the enclosing of the present loop structure in reinforced concrete, so as to deaden the noise partially, and to strengthen it so as to carry the additional roadbed. (See Plates XXXII, XXXIII and XXXIV.) I planned to put the ties in a bed of crushed stone, supported upon concrete slabs having aprons built up at each side of the structure to the level of the car floors, coming to about level with the car platforms as shown in detail in Plate XXXIII. I claim that with concrete reinforcement over the present steel structure, and these aprons as part of the structure extending continuously at the sides of the cars, we would so reduce the noise and so confine what was left of it underneath the bodies of the cars as to practically eliminate the noises of the loop which are now so objectionable as they reverberate around and through the buildings adjoining the loop structure.

At the time these recommendations were made, some of my railroad friends got up before the Transportation Committee of the City Council and said it was absolutely impossible to make concrete stick to an elevated steel structure under vibration such as this structure had to stand. Nevertheless, while I do not know that it had been done at that time, I do know that many railroads in the country have since reinforced steel structures in the way I then recommended and the concrete is hanging on well; also that other elevated railroad structures have been similarly reinforced since, so if my elevated railroad friends have the desire and the money they can also do it, and deaden the noise.

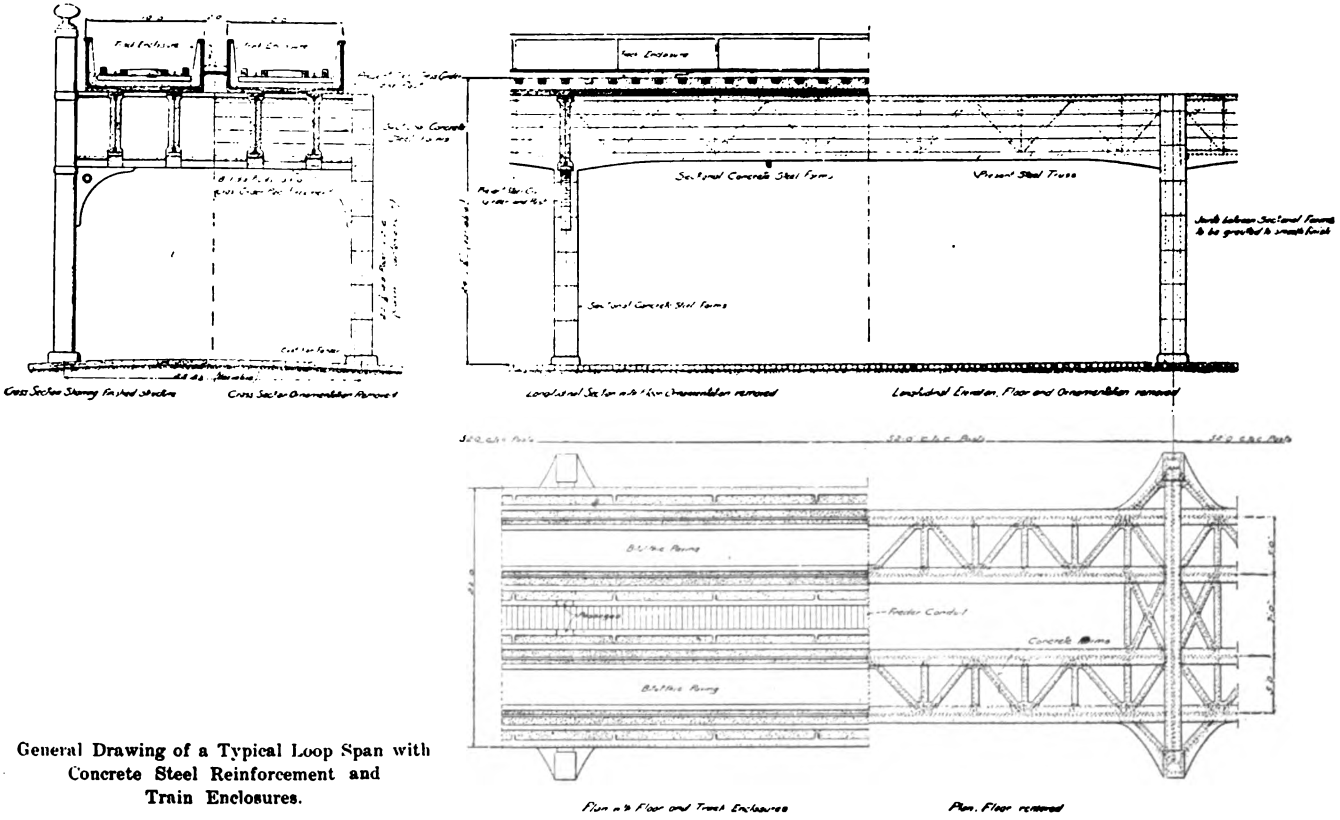

Train Enclosure
Train Enclosure
Train Enclosure
Sectional Concrete Steel Forms
Present Steel Truss
Joints between Sectional Forms to be grouted to smooth finish
Sectional Concrete Steel Forms
Cross Section Showing Finished Structure
Cross Section Ornamentation Removed
Longitudinal Section with Floor Ornamentation removed
Longitudinal Elevation, Floor and Ornamentation removed
52.0 c. to c. Posts
52.0 c. to c. Posts
52.0 c. to c. Posts
Bitulithic Paving
Passageway
Feeder Conduit
Concrete Forms
Bitulithic Paving
Plan with Floor and Track Enclosures
Plan, Floor removed

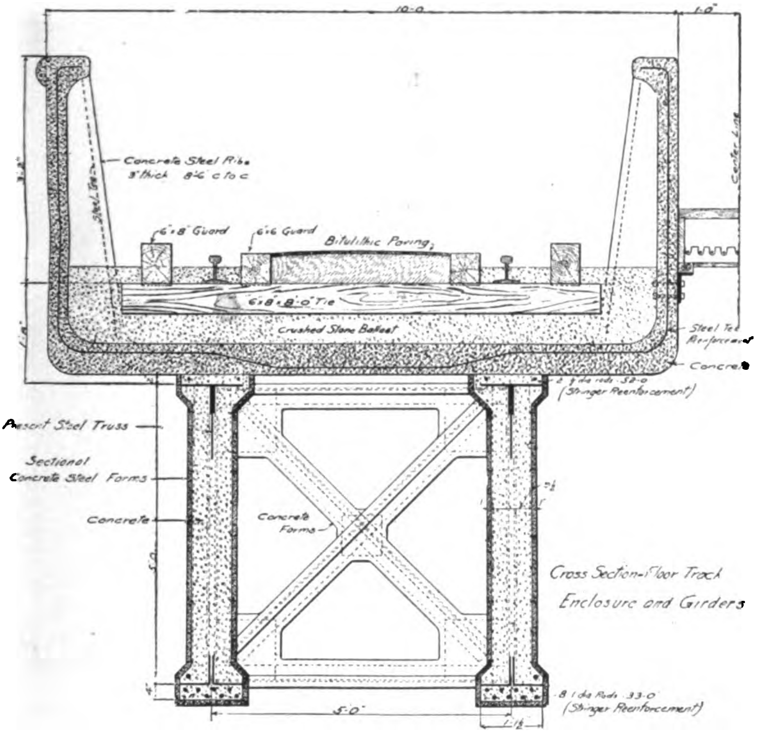
Plate XXXII.

General Drawing of a Typical Loop Span with Concrete Steel Reinforcement and Train Enclosures.

Have I answered your question?

Mr. Vent: Yes.

In regard to increasing the property values. Suppose you take your Madison Street subway, loop around Grant Park and your through-route Clark Street subway, running from 18th to Elm Streets, and instead of that subway put in a modern elevated structure. Would that increase property values as much as the subway would from the statistics you have now?



Transverse Section of Typical Loop Span with Concrete Steel Reinforcement and Track Enclosures.

Plate XXXIII.

The Author: If you have listened to the arguments of the Loop Protective Association of this city, as to how much the elevated structure has decreased the value of Wabash Avenue property, you might have your question answered, perhaps.

Mr. Vent: I realize that the Wabash Avenue elevated is not properly designed, too many cross-overs, and too much congestion. That could be remedied by proper construction.

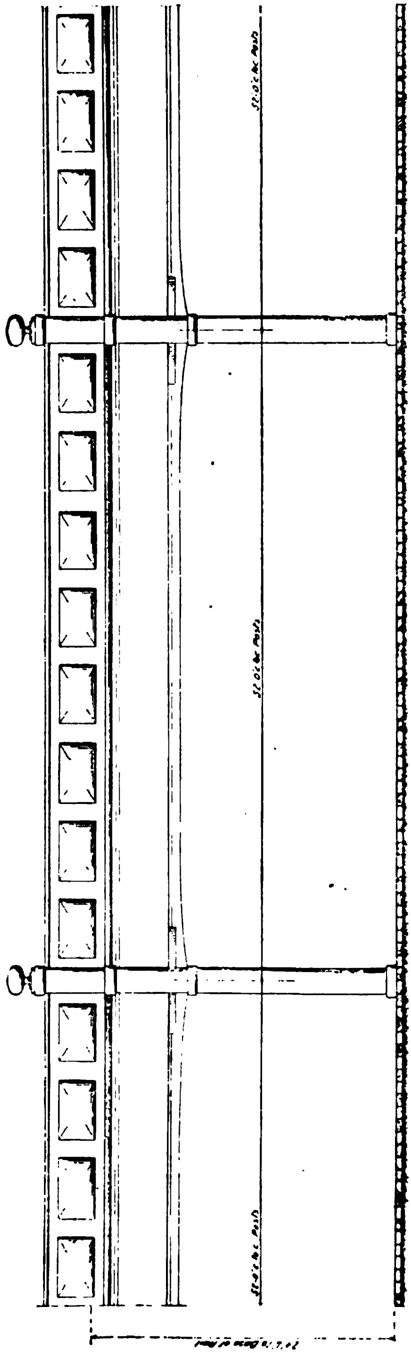
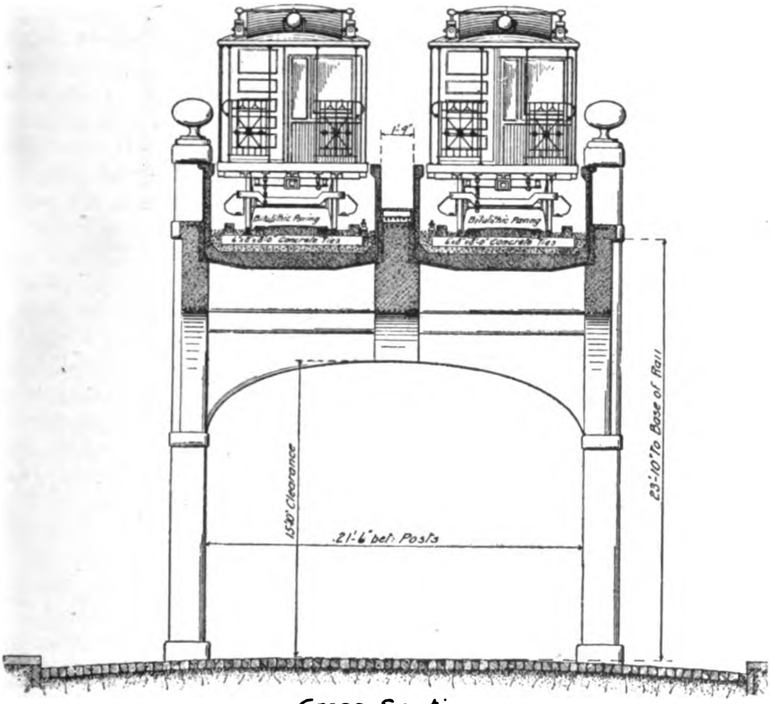


Plate XXXIV.

Present Loop Structure Showing Concrete Steel Reinforcement and Track Enclosure Applied with Ornamental Finish.

The Author: I agree with you entirely that an elevated structure could be erected which would be much less noisy than the present one, and such a structure would not be nearly as objectionable as the present type of structure; but as to whether or not the property owners would consider it an advantage or disadvantage to the property, I am not prepared to say. My opinion is they would consider it a disadvantage because of the view that has always been taken in this city against elevated structures. Plates XXXV and XXXVI show such a structure, this design being what I suggested in my 1905 report for new elevated railroad structures in case they were built.



Transverse Section of Suggested Concrete Structure.

Plate XXXV.

In my 1902 report I said one way of increasing the capacity of these elevated roads was to build four loops,—by cutting the present loop in two and giving each elevated road a separate loop in the business district. This could be done by building an elevated structure above Clark Street, from Van Buren to Lake Streets, and one above Monroe Street, from Fifth Avenue to Wabash Avenue. But

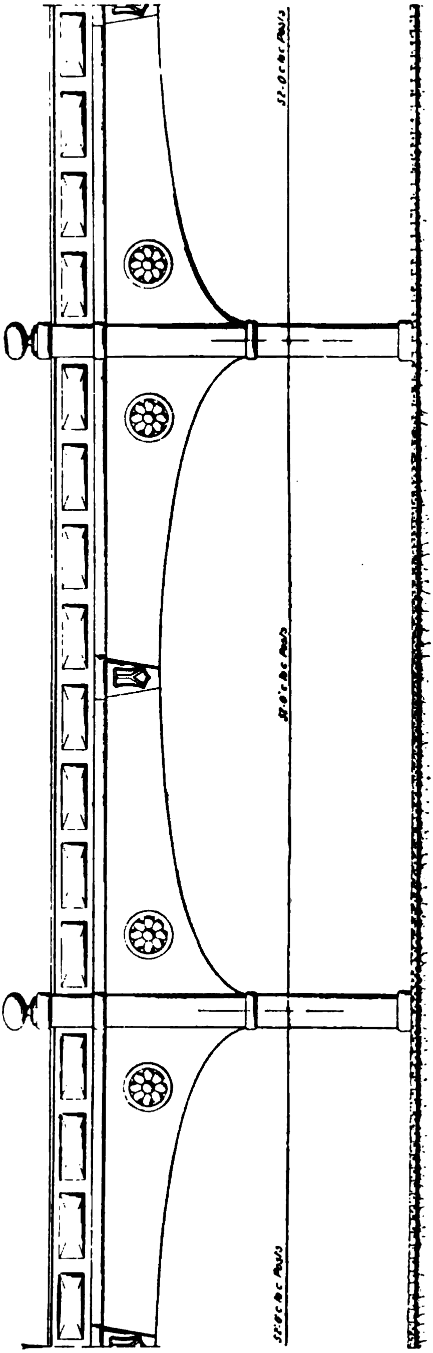


Plate XXXVI.

Longitudinal Elevation of Suggested Concrete Elevated Railroad Structure.

I knew the suggestion would not be accepted, and I said so. The sentiment of the community is against additional elevated structures, at least in the present congested business district, and probably that is an exaggerated antagonism, due to the fact that improper elevated structures have been built here. I do not mean by that statement that they were not all right at the time they were built, because they were up to the engineering practice of that date, but I do think that if an elevated structure could be built now along modern lines and the lines suggested, it would be much less objectionable to the people, and it is possible that their objections might be overcome, and that they might permit an elevated structure. But I have never dared to hope for that, and have never advocated the extension of the elevated structure in the congested district. There is no doubt that an elevated structure could be made to take care of the traffic, but I do not think it would increase the value of the property as the subway would.

Mr. Vent: What is the ratio of cost of a subway to an elevated structure? I believe it is at least three to one.

The Author: A subway would cost from two to three times, per mile of single track, what a standard elevated road would cost.

Mr. Vent: I wanted to get your opinion as to economic conditions, disregarding the people along the streets, for the benefit of people away out who probably do not own any property there, and who do not have their business in certain congested districts. As an economic proposition, don't you think the elevated proposition would be the cheapest?

The Author: Without any doubt it would be the less expensive method.

Mr. Vent: Such a plan would probably serve the community at large as well, would it not?

The Author: This is what I have said in my statement, that what we were trying to do here was to build just enough subway to meet the situation in such territory where it could be supported, utilizing the elevated structures in such territory as they occupy for rapid transit lines, because they then would take the place of subways. I firmly believe the logical plan for a subway system, if we are acting on a plan which will be most acceptable presumably to the people, is a subway in the most congested district, an elevated structure in the next most congested district, then surface lines from that point. That is in the order of he economics of the thing. As time goes on and people will not longer countenance the elevated road, it will have to be taken down and put in the ground. That has never been done yet anywhere that I know of, but this is what they talk. I am not certain at all that they will take away this loop structure or that they will take down any of this elevated railroad, but by means of subways they will increase the capacity of this downtown district into which they cannot bring more elevated tracks.

Now, as an elevated investment, you can afford to invest from two and a half to four dollars in surface lines properties for every dollar of gross receipts you take in. For an elevated road, from four to six dollars. In a subway you can afford to invest from six to ten dollars for every dollar of increased gross receipts. This is for the reason that on a surface street car line, while the first cost of it is less, the rate of speed is lower, and the platform expense is higher. On such roads unit cars, as a rule, are run so you must have a motorman and a conductor for each car.

The speed being low, the capacity is lower than an elevated road, and much lower than a subway. Consequently you can only afford to invest a certain amount of money or from two and a half to four dollars for each dollar of gross receipts. On an elevated road trains are longer and you can run them faster. One conductor is sufficient for a train, and a guard for every two cars. When the platform expense runs down you also carry more people, so you can afford to invest more dollars. In other words, your operating expenses are lower. In the subway, where you can run high speed ten-car trains at frequent intervals, because you have no street obstructions or heavy grades, you can afford to invest from six to ten dollars for each dollar of gross receipts because you can carry the people so much cheaper, ***but the people must be there to carry.*** You run a ten-car train loaded with people, say seven or eight miles, in a very short space of time, and you do that with one motor man and with four or five guards. You run very rapidly, you only consume a short space of time, therefore the services of those men who are running the train have only been required for a short space of time. At the end of the run you reverse that train and those men are kept busy all day long running up and down at high speed, earning more for the company for their daily wage than they could on surface or elevated lines, and that is why you carry people cheaper than on the elevated roads and cheaper than you do on the surface cars.

Mr. Vent: I think on the elevated road you can run from Congress Street to Indiana Avenue in seven minutes. That is about as far as from Harvard Square to Park Street, Boston. There is no reason why you cannot run elevated trains as fast as in the subway.

The Author: No, there is no reason if the railroad is as good, but there is some hesitation about running as fast in the air as in the ground. It is a fact they do not run elevated trains as fast as they do subway trains. The only reason, taking the ordinary condition, is the idea of the sense of safety. Take the interborough subway. The average speed of express trains is a little over 24 miles per hour. The average speed of local trains is about 13 miles per hour. The average speed over the South Side elevated roads here used to be 13 miles per hour. I do not know just what it is now. There was one time when the multiple unit scheme of train control was first put on that road that the average special was about 19 miles per hour. I think the speed is now about 13 miles per hour on the local trains.

Mr. Vent: Take the express service, there the average speed is practically the maximum.

Seven minutes from Congress Street down to Indiana Avenue station would be four miles in seven minutes, about 30 miles an hour.

J. R. Bibbins: The speed is about 14 miles for the local trains and about 18 miles for the express trains, including stops.

The Author: There are some stops. Mr. Bibbins says the average speed of the locals is about 14 miles, and of the express trains 18 miles per hour. Of course, if you run far enough and do not stop you get a high average speed, but I am speaking of the interborough subway. They have stops not over a mile apart. They will not average a mile apart, I believe, and still, averaging a stop every mile or less than that, they make an average speed of 24 miles per hour. The maximum speed is 37 miles per hour, unless they get a down-grade run, when they secure 40 miles, but the motors are only wired to run 37 miles per hour, and with a straight-away run that is what they make. But in riding in that subway one feels some sense of security, while up on an elevated structure, going 37 to 40 miles an hour, one thinks he is going very fast.

Mr. Vent: I would rather be on the elevated than in the subway.

The Author: I do not want to argue that question, for it is a matter of personal opinion. You are not confined, that is true, as you are in the subway.

Here is an interesting statement on the subway question:

> "When New York was the same size as Chicago now is, it earned only $22,000,000 per year in transportation. Chicago earns $35,000,000, including surface and elevated lines."

The two cities are on an entirely different plane of earning capacity. As I pointed out before, New York is a long, narrow city, greatly congested. Chicago is fanned out. But the statement that Chicago earned $35,000,000, as against New York's $22,000,000 when of the same size as Chicago, does not mean exactly what it might seem to mean. It simply means that the methods of transporting passengers were different and that the riding habit had not been developed in New York at the time it was the size Chicago now is, to what the Chicago riding habit now has developed. I think if we were to put a subway down in New York today, and then put a subway down in Chicago when it has reached New York's present population, there would not be that difference, because the methods of transportation are now the same and they have developed the riding habit there to about the greatest extent they possibly can, with the present capacity of the subway.

A Member: I would like to ask one question, if I may. It seems to me that if we could stir up public opinion to close the loop district to standing vehicles and use it for street cars, we could help the situation at the present time while waiting for subways.

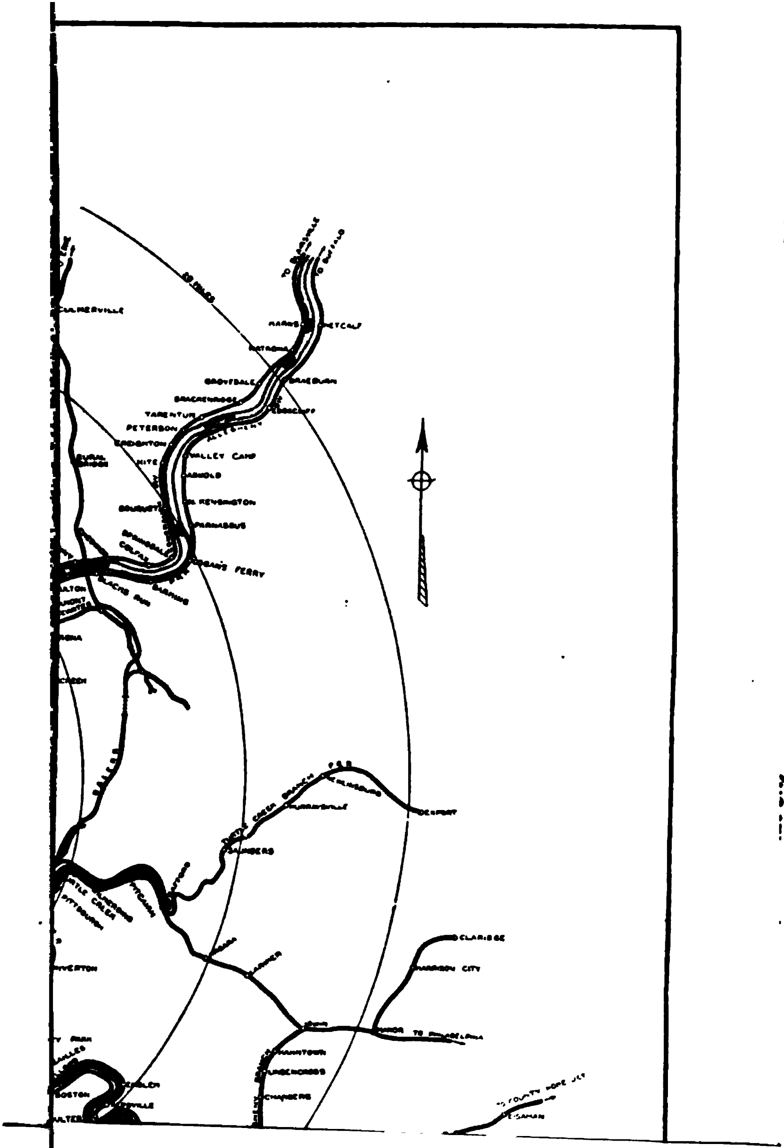
The Author: I have an idea that I think is better than that,

t
f
h
u
s
a
S
le
b
tl
b
C
st
w
fe
st
th
a
c
s
n
a
g
i
d
r
h

t
p
r

ompai
the Bc
on, Ct

Western Society of Engineers.
Vol. XIX. No. 4, Apr., 1914.
Arnold—City Transportation.
Plate XXX



DAT

Height of Sides in ft	SIDES OUT	REMARKS	
2	B	$\frac{0.25}{0.131} = 1.91$	
2	B	$\frac{0.25}{0.147} = 1.7$	
1½	B	$\frac{0.25}{2.345} = 1.065$	
1½	B	Questionable Plate	
1	B	$\frac{0.25}{0.12} = 2.08$	
1	B	$\frac{0.25}{0.120} = 2.08$	+
2	B C	$\frac{0.25}{0.1473} = 1.7$	+
1½	B C	$\frac{0.25}{0.289} = 0.865$	+5
1½	B C	$\frac{0.25}{0.2562} = 0.975$	+4
1	B C	$\frac{0.25}{0.1038} = 2.4$	+1.
1	B C	$\frac{0.25}{0.2019} = 1.24$	+3.

THE MAKING OF A TECHNICAL JOURNAL

E. J. Mehren,* Jun. Am. Soc. C. E.

Presented February 2, 1914.

In addressing this Society on the subject assigned it may safely be assumed that all of you are sufficiently acquainted with the aims of technical journals to allow an extended discussion of their objects and scope to be dispensed with. These points, therefore, will be but briefly treated.

Primarily the technical journal—and in this talk the term "technical journal" will be considered synonymous with "engineering journal"—was established to supply the engineer with information as to the latest developments in his field. If this had remained its sole object it would be on practically the same basis as the journal of an engineering society. It was recognized in the early days of technical journalism, however, that execution was quite as important in engineering as design, and space was, therefore, devoted to the methods employed in carrying out the works planned by the engineer. Naturally the contractor or builder was interested in construction methods. He became a reader and to serve him better it was a logical step to give space to descriptions of construction equipment and news of proposed enterprises. Moreover, manufacturers spend millions of dollars annually in investigations and experiments, which come to light, as a rule, only through improvements in their products. To neglect these products, then, is, journalistically, to cast aside the fruits of much well-spent money and leave unknown devices which may be the means of large savings to the readers.

The technical journal of today, therefore, is not strictly a professional journal. It emphasizes quite strongly the business side of the profession. As an evidence of its work along these lines we may recall the contracting news sections which occupy a place of much importance in many technical journals.

EDITORIAL ORGANIZATION

The object of a technical journal being to gather from all parts of the country, and of the world for that matter, data and news of value to its clientele, the collecting organization must evidently be an extensive one. The machinery for gathering this material can be classified under three heads:

1. A permanently employed editorial force.
2. Correspondents and contributors.
3. A comprehensive clipping service.

The permanently employed editorial staffs of the larger engineering journals have as many as nine or ten editors, supplemented by as many trained clerical assistants. All of the editors have an engineering training. Most of the editors will be located at the main office of the journal, while the character of the specialty covered will govern the points at which the others will be located. For a paper deeply interested in metallurgical processes editors may be located in Pittsburgh and Denver, while in the general field, if the headquarters are in New York, one or two men will be located in Chicago and one on the Pacific Coast. The staff generally includes four or five specialists, confining their attention to one, or at most, two lines, and a number of general men.

---

*Editor, Engineering Record.

Correspondents are located in every large city throughout the country and are relied upon to furnish promptly news of special interest to the journal. They are subject to call by wire or letter for special information which will guide the editor as to the importance of any particular item of news. If extended treatment of the subject is needed he may call on one of the journal's particularly good friends in that location—a specialist in the subject, if possible—to prepare the article or may send a member of the staff to cover it.

The clipping service is supplied in part by clipping bureaus and in part by a department in the head office of the journal which reads representative newspapers from every part of the country. The clippings, however, are not assumed to be correct and are used simply as clues, to be followed by letter or telegraphic verification, and, in the case of important matters, by personal attention of a correspondent or member of the staff.

The secret of prompt and reliable news gathering lies in the development of a strong and interested clientele. Such a clientele is the chief asset of a technical journal and so carefully has it been fostered by the older magazines that the correspondents consider their posts as places of honor and are proud to be identified with the journal. Not only does a proper clientele respond quickly in emergencies but, by its friendly criticism, aids the editor in estimating the needs of his field.

STAFF ASSIGNMENTS

In the case of matters of great importance, such as disasters to large engineering structures, reliance is seldom placed upon outside contributors. There is generally so much at stake that only a trained editor can appreciate the need for speed and the danger, in the case of a disaster, of falsely interpreting the occurrence or the causes. When a big matter of this kind "breaks", as it is put in editorial language, the conditions are much the same as in a newspaper office. There is a marshalling of forces, a staff conference so that every brain in the organization may be racked for clues as to probable sources of information, telegrams to get as definite information as possible, and then a quickly formed plan for covering the emergency.

For example, when the seriousness of the Dayton flood was realized there was an exchange of telegrams between the Chicago and the New York offices of our journal and our Pittsburgh correspondent. The conclusion was to send the Western Editor from

Chicago to attempt to get into the flooded district from the north, and to dispatch two representatives from Pittsburgh to attack the situation from the east. They were given no orders except to get in, gather the material and get it on the wire. In such a case instructions are useless and sole reliance must be placed upon the initiative, the energy, and the judgment of the staff members assigned. As these men were starting, telegrams were poured into every city affected and correspondents urged to dispatch authentic material immediately. The New York offices of important companies owning or operating properties in the affected region were communicated with by telephone and urged to keep the editorial office advised of all developments. As a result, in the issue of the week following the flood there was a six-page report giving authentic data upon the disaster, and accompanying it was an insert plate with pictures of destruction at strategic points.

COVERING THE DAYTON FLOOD

That the life of the technical editor is not less exciting at such times than that of the newspaper man is evident from the following extracts from the report of the editor who got into Dayton from the north. He has something to say, too, about the power of the technical press. It may be noted, incidentally, that within 12 hours after leaving Chicago, he had a military pass which enabled him to go anywhere in the flooded territory.

"Never before," he says, "did I realize the power of the engineering press with the ordinary layman. A card with the name of the journal in the corner was as good, practically, as a Governor's pass. True I had a military pass to allow me to go anywhere, but to say that one represented the ENGINEERING RECORD, a New York engineering magazine, was sufficient to pass one almost anywhere.

"Another evidence of this power was the reception which I received from Mr. John H. Patterson, president of the National Cash Register Company, and head of the Relief Committee at Dayton. As soon as I handed in my card Mr. Patterson singled me out among the crowd, asked me in, and spent fifteen minutes of his valuable time explaining this situation. He said that I was the first representative of an engineering paper on the job and that he was glad to see what we could do to help him. He took me to his private office, and after explaining the local situation briefly, spent about a half hour, giving me in succinct shape the full situation from the layman's standpoint.

"To get to Mr. Patterson I went to one of the relief stations and stated that I was an engineer and wanted to get to Mr. Patterson, and also that I represented the ENGINEERING RECORD. A relief automobile going across town some five miles to the National Cash Register plant was almost immediately available and I was taken there in double-quick time.

"From my experience with Mr. Patterson I should say that he appreciated very much more, perhaps, than I did myself the power and influence which any statements made in the editorial columns of the ENGINEERING RECORD might have with the general public and possibly even with the Government itself.

"As some sidelights upon my experience I might mention my experience with the camera. As all able-bodied men were impressed into service if they were at all suspected of being idlers or sightseers I felt it necessary to carry the camera concealed. Carrying a tripod was out of the question and all of my pictures were taken either snap-shot or resting against something.

"A bar of chocolate in one's pocket enabled him to eat two meals a day only and keep going from morning till night.

"Mr. S. (one of the representatives who worked west from Pittsburgh) carried with him two bottles, one of hypo and one of thiosulphate. With these he was able to drink any water he came to. As for myself, after leaving Toledo, I drank nothing in the way of water for at least four days. After meeting S. at the Hotel Algonquin, in Dayton, I took my first drink of water, after it had been duly dosed with hypo and brought back to normal taste with the thio."

COVERING A DAM FAILURE IN WEST VIRGINIA

As another instance of hardship suffered in gathering data for the technical press may be cited the occurrences at the time of the recent failure of a concrete dam on the Stony River, in West Virginia. There was the usual marshalling of forces and the dispatching of one of the editors to the scene. A trunk line railroad runs within 15 miles of the dam site, but from that point the only transportation is over a logging spur. The editor arrived at the junction with the spur on Saturday morning, January 17th, two days after the dam failed and found a driving blizzard crippling the branch road. Nothing could be done that day and at 5 o'clock on Sunday morning he began to walk to the dam site, following the railroad right-of-way, plodding through heavy snow into which he sank from a few inches to two feet at each step. The scene was reached, notes made, conclusions formed and photographs taken in time to catch the logging train, which had just extricated itself from the drifts. In 24 hours the films were developed, the story written and material being put in type.

CONTRIBUTORS

A word now regarding those who supply material to the technical journal—the contributors and editors.

The number of engineering contributors is very rapidly increasing. The managing editor of our journal stated several days ago that if no additional contributions were received for the next four months the supply on hand would be ample to fill the space which will be available after matters requiring immediate attention have been provided for. All of the material is of first-class quality. Its great fault, however, is in its length and this fault is characteristic of practically all contributed material. The engineer naturally feels that his own project is of transcendent importance and, instead of picking out the unusual or most interesting features, he describes details that are of interest only to himself and to his associates in the work. The result is not only a great waste of his own time but the probable rejection of the manuscript. Many contributors, fortunately, are willing to revise their manuscripts in accordance with the suggestions of the editor, or to allow the editor to cut them down. It not infrequently happens that an article rejected solely because of its length, is returned cut down one-half. The resulting article is much better than the first draft and the reader saves time.

Every reader of a technical publication should be a potential contributor. Certainly at least once a year something comes up in his practice that is worth while passing on to his brothers. If he will put it in the shortest possible form his effort will receive a hearty welcome from the technical editor. Five one-column articles are preferable to one five-column article.

EDITORS

As to the editorial staff itself no single problem in technical journalism offers so much difficulty. The men must be engineers by education and preferably by experience, must have ability as writers, and last but not least, must have strong personalities, because only such can deal forcefully with situations and make the impression necessary to secure the confidence of the engineers with whom they deal. If some formulae could be devised by which such men could be infallibly picked the saving of time to the editor-in-chief would be very large. As it is now only men of apparently special aptitude are given a trial, and even then the mortality is at least 50 per cent. The work of training is laborious and long. Throughout this period, and in fact at all times, these slogans are emphasized in our organization by the editor and the older staff men:

1. Absolute accuracy—this journal cannot afford to take a chance.
2. Get the news first—it spells journalistic success.
3. The way to get information is to go after it—work your field unceasingly.
4. We have no room for reporters—do your share of the editorial thinking.

We impress upon them, moreover, that to be the editor or associate editor of a great engineering paper is not a job—it is a career. This has been frequently said and only the man who appreciates it thoroughly is apt to reach eminence in his work.

THE TROUBLES OF EDITORS

Some of the difficulties experienced by the technical editor may help to a clearer comprehension of the work involved in the making of a technical journal.

Probably the chief difficulty is presented by the tremendous amount of material which daily must pass over the editor's desk. This consists not only of routine letters, but contributed and staff articles, with their accompanying blue-prints and photographs, special and annual reports, press bulletins, proceedings of technical societies, clippings, catalogues, and a mass of miscellaneous material. It is a conservative estimate, leaving aside bulky printed reports, that fully twenty times as much printable material passes over the editor's desk as is actually used. But whatever the material, it cannot be passed over slightingly but must be examined by some one familiar with the policy of the journal, and the history of each of the principal engineering specialties, in order that the new may be separated from the old, the correct from the incorrect, and that articles with "an axe to grind," or which may injure the character or professional reputation of an engineer may be discovered. From one end of the day to the other decisions must be made. There is little chance for reflection and careful study. Reliance must be placed upon a good memory, accurate judgment, and intuition developed by long experience.

There is imposed upon the technical editor, naturally, a very grave responsibility. By passing judgment without having all the facts clearly before him he may seriously prejudice engineers and the public against a meritorious project, may injure the reputation of a practitioner and may permanently affect the standing of his journal. This responsibility is fully appreciated in the offices of the higher class technical publications, and sooner than do damage, in doubtful cases, to the reputation of an individual or an organization judgment will be reserved even if there is danger of being accused of being weak.

DEPARTMENTS OF THE TECHNICAL JOURNAL

Of the purely technical side of engineering journals it is not necessary to speak. That has been sufficiently covered in describing the qualifications of contributors and editors, and pointing out some of the difficulties of the latter. The other divisions, moreover, are much less likely to have had your attention.

We have often been asked how it is that the technical journal manages to cover in its editorial columns so wide a range and to speak with authority on so many fields of engineering. The method is the very natural one of staff specialization. One editor is responsible for each of the main branches of engineering to which the journal is devoted and his duty is to follow the developments so closely that he can speak authoritatively on his specialty or specialties. Moreover, by constant contact with the leaders of the field, the pros and cons of controversial matters are known, so that when the time comes to speak the application of the journal's general policy to the situation in hand allows conclusions to be formed quickly.

It is true that the technical journalist does not originate. It is for those in professional practice to make the advances. The journalist's duty is to observe and interpret them. While, therefore, he is likely to lose his appreciation of details, that loss is more than compensated for by the advantage of being able to stand off at a distance and to observe a movement or a new process without the warping tendencies which comes from too close attention to details. In this way the technical editor should be able to see the philosophy of the development going on under his eye and to present aspects and relations that will be an inspiration to those whose duties keep them closely confined to details or to one specialty.

NEWS SECTION

In recent years there has been a marked tendency to emphasize the news pages of the technical journal. Ten years ago these were quite subordinate. When important events occurred they were duly chronicled, because it was quite evident that the field would be interested in them. It was not appreciated, however, that a bird's-eye-view of the field for the week came not from the mere reporting of the outstanding events but from gathering up from the four corners those little items which more surely denote the general tendencies. For that reason the development has been toward a great many short items, written in newspaper style, so that they could be passed over readily, leaving the reader in an hour with a complete survey of the field for the week.

With this tendency to give more attention to current news has come also an appreciation of the necessity of appealing to the human side of the engineer. The technical journal of the past has been characterized by a "deadly sameness," which tempted one to leave his copy in the wrapper until it was time to send the whole volume to the binder. The type arrangement did not change from year to year, illustrations did not receive adequate attention, and the editor scrupulously blue-penciled any sentences or phrases that had in them the least human interest.

The sentiment in the offices of technical journals, however, is changing rapidly. More and more appeal is being made to educated and uneducated alike through pictures rather than through the printed word. The picture gives an immediate impression—the word is a slower medium. Moreover, printing itself has undergone rapid changes and standards have been erected which have raised typography to the level of an art. These things are taking hold upon technical editors. The evidence can be found in many journals of the present day and portend marked improvements within the next few years. The changes are being made, too, without detracting from the technical excellence of the journals.

LESSONS FROM THE NEWSPAPER

Moreover, much is being learned from the newspaper. Long articles are in disfavor, the "story form" is being applied in technical descriptions, while "heads" are being written that for crispness and informative value compares well with those used in the newspapers. As to the story form, it may be noted that particular emphasis is being placed upon the correct writing of the introduction to the article. Unless the first paragraph shows the reader why he should read the whole article, the copy goes back to the sub-editor for rewriting. A rapid style and directness are insisted upon, so that the reader may be carried without distraction by useless details from the first paragraph even to the end of the article. There is still much room for improvement, but the evidence indicates that the standards of the newspaper and of the high class popular magazine will in the near future banish the "deadly sameness" referred to.

PLACE OF THE ADVERTISER IN TECHNICAL JOURNALISM

It is hardly necessary to point out that if magazines did not have advertisers the technical journal as we know it today could not exist. It costs from $12.00 to $17.00 per annum to send a high-class technical journal to a subscriber, yet he pays but $3.00 or $5.00 for it. From $9.00 to $12.00 must, therefore, be taken from the advertising revenue and paid out in expenses for each subscriber on the list. That advertising is necessary in the technical journal is, therefore, not open for argument.

There has come about a very marked change in the attitude of manufacturers who use space in engineering magazines. In former days the signing of an advertising contract was considered by many advertisers as guaranteeing to them a certain amount of space in the editorial pages, wherein their products would be "boomed" and personal notes about members of the organization printed. Weaker papers did allow their editorial pages to be thus prostituted, but while the best papers from their very foundation, 35 to 50 years ago, have not permitted this, it is only recently that advertisers have seen the light and have concluded that a journal which does sell itself editorially cannot gain or hold the confidence of its readers and is, therefore, not a good advertising medium.

The attitude of the high class technical journal toward the manufacturer and his product is that those materials which are actually of value to readers will be described just as they are brought out. In other words, the theory underlying it is the same as that underlying the publication of technical matter, and the fact that the manufacturer is or is not an advertiser is a matter of indifference to the editor, so far as description of product goes. Succinctly put: While the advertising manager will not use anything that is not paid for, the editor will not use anything that is paid for, whether in money or any other consideration.

In another direction, however, the demands of the advertiser are very rapidly increasing—and justly so. Whereas formerly he bought space in technical journals because he liked the solicitor or had a vague idea that the paper helped him sell his goods, he now demands classified circulation statements, showing how many readers the journal has in each of the several branches which it covers and showing also the geographical distribution of the readers. As an indication of the searching inquiries made, some of the questions recently asked by one of the subsidiaries of the United States Steel Corporation are here quoted.

"Give a brief outline of the periodical's history.

"What distinguishes this periodical in character from others of similar purpose?

"What is its editorial equipment for giving such service?

"What determines the limit of number of subscribers obtainable for the periodical and what is the estimated limit?

"What is its equipment for getting and keeping subscribers?

"Is a copy service department sustained at the expense of the journal for preparing copy for advertisements?

"Will the publisher allow the advertiser to make a complete examination of the circulation at any time?

"What average circulation is guaranteed for the coming year?"

In addition to these were many rather perfunctory questions and also blanks for the circulation analysis above mentioned.

It can be readily appreciated that if an advertiser will go to this length in determining the suitability of a medium he will endeavor to use the space to the greatest advantage. As a matter of fact, this is exactly what is happening, so that the advertising pages of any high-class paper will now be found to contain information of much value. Most journals maintain copy or ad-writing departments, employing at least several engineers. That the service is being appreciated by the reader is evidenced by the good returns which advertisers receive and by the suggestions which come in occasionally for the improvement of a certain advertisement or of the advertising pages as a whole. In this connection it should be said that publishers are just as grateful for suggestions regarding improvements in the advertising pages as they are for changes in the editorial section, for they fully appreciate that any improvement in the technical quality of the advertising pages not only helps the advertiser, but also raises the standing of the journal and increases its value to the reader. "Read the advertising in technical journals" is a slogan in the senior class in many of our engineering colleges.

In this connection it may interest the younger engineers to know that there is a good field developing here for the application of engineering talent. Several times recently heads of service departments have declared that their great need was for advertising writers with engineering training. While the work leads out of the practice of engineering, the chances for promotion into the advertising or business departments are excellent and offer work that is well paid and that is attractive to men adapted thereto.

THE FUTURE OF TECHNICAL JOURNALISM

What will be the future of technical journalism? Those in the work who are gifted with visions see wonderful opportunities for expansion and better service to the clientele. Beyond that, however, is an ideal to which the technical journal should be and is aspiring—to play a larger part in educating the public in matters having an engineering aspect. Right thinking is needed, for example, on the part of the people at large regarding the valuation of public utilities for purposes of rate making. Theories widely prevalent are confiscatory of private property. What agency is so well fitted as the technical journal to expound sound doctrine? What medium is more suitable for linking up scientific principles, facts, and the public interests on such matters as the pollution of streams, the prevention of floods, the sane development and financing of highway systems, and the writing of building codes? All of these rest on an engineering basis.

Furthermore, the public needs education as to the status of engineers and the advisability of appointing them to public office largely concerned with engineering work. Here again the technical journal should be qualified to speak.

But how can that influence be exercised? The general public does not read engineering magazines. The scheme is to exercise that influence on the newspapers of the country and have them pass the doctrines on to their readers. Already great progress has been made along these lines and better relations are established today between the technical press and the newspaper editors than ever before. Important and interesting items are taken from the journal each week, boiled down, freed from technicalities and distributed to the newspapers of the country. The result is a weekly broad dissemination of engineering information. Much of it is descriptive merely, but at the same time the newspaper editor is getting more familiar with it and is being favorably disposed to the journal. That is the first step to his confidence. When that is won he will not need to be urged, but of his own volition will turn to the technical journal for counsel when an important engineering matter is at issue.

THE PLACE OF THE ENGINEERING SOCIETY

But the technical journal should not be alone in this work. Working side by side with it should be the local society. Your position being disinterested, you can readily get the ear of the city editor, and appropriate public policy and publicity committees should thus be able to make the society a factor in local affairs. You have an opportunity as great as that of the national engineering society. It can concern itself only with national issues and can speak only when the issue is unusually clear cut, for local conditions make for radically different views on all large questions. Unanimity, therefore, is almost out of the question on public affairs, except on a few transcendent matters. In the local society, however, it should be much easier to reach agreement as to policy. The advocacy of engineers on public service commissions, or of the establishment of commissions to study engineering problems affecting the public health, whether as to water supply, sewage treatment, garbage disposal, street cleaning or sanitation of industrial plants, all come within the purview of the local engineering society. In the mechanical field there are equally important issues, particularly as to legislation on safety devices, boilers, boiler inspection, etc.

In this connection let me emphasize another aspect of the engineer and publicity. There is altogether too much suppression of technical news. The reporter is not wanted, on the general theory that he is indifferent as to facts. That broad assertion is in general not true. He does want to present facts properly, but if the information is given him in technical terms it is not to be expected that his version will pass engineering analysis. It is good policy to make an effort to be pleasant to him and see that he understands what he is getting—for the first canon of newspaper work is to "get the news," and he is bound to get something, right or wrong. Without assistance or against opposition, the account may be incorrect and grossly unjust to the engineer or owner. If such is the case, the engineer in most cases has himself to blame.

Finally, it is a fair question as to the relations of the local society and the technical journal. The latter can do two things for the society: First, assist it in its technical work by reprinting abstracts of important papers, giving due credit, of course, to the society; and, second, by publishing news as to its public activities, encourage all organizations of the same type to assert themselves, and thus do their part in spreading the influence of the engineer and raising his status. The technical journal and the society have, in the last analysis, the same aim—the good of the profession. They should be partners, each working effectively within its own sphere. Some things the society can do better than the technical journal, on account of its close organization and personal contact; some things the journal can do the better through its wider audience. Both should realize their copartnership, for such realization is the forerunner of co-operation, and by co-operation they will the more effectively carry out their program—the advancement of the profession and of professional knowledge.

IN MEMORIAM

ROBERT STROTHER DRAPER, ASSOC. W. S. E.

Died March 17, 1914.

Robert Strother Draper was born in Chicago, Illinois, August 16, 1883. He was the son of Henry C. and Ellen E. Draper.

He attended the public schools of Chicago, also Armour Scientific Academy, where he graduated in June, 1899. He attended Armour Institute of Technology from 1900 to 1903, leaving in the spring of 1903 to enter the employ of F. A. Peckham in general railroad contracting. Mr. Draper's early engineering training covered a wide field, and while still in his teens he had held positions as Topographer and Draftsman with the Illinois & Rock River Electric Railway, summer of 1900; Draftsman with Holabird & Roche, Architects, summer of 1901; Inspector and Chief Clerk, Engineering Construction, Missouri Pacific Railway, fall of 1901; Topographer, Atchison, Topeka & Santa Fe Railway, summer of 1902. In the fall of 1903 Mr. Draper was made Assistant Engineer, Chicago Junction Railway, on track elevation work, and in this position he designed most of their masonry construction. After this work was completed in 1907 he was engaged as Engineer and Salesman for the Trussed Concrete Steel Company at Detroit, leaving them in 1908 to accept a position as Salesman with the Weber Chimney Company of Chicago. In 1909 Mr. Draper went with the General Concrete Construction Company as Contracting Engineer and Sales Manager, which position he held until the time of his death. He was also Vice-President of the General Steel Products Co.

Mr. Draper had specialized in concrete construction and had designed a great many reinforced concrete chimneys, grain elevators, and tanks. His professional career was largely influenced by his father, Henry Clinton Draper, a prominent Railroad Engineer and a highly respected member of this Society, who died May 23, 1903.

In 1902 Mr. Draper married Miss Ruth Clarkson, of Chicago, who with a four-year-old daughter, Virginia, survive him.

Mr. Draper joined the Western Society of Engineers in 1906 as a Junior Member and was transferred to Associate Member grade in 1911. He was a member of the Union League Club and the Masonic Order.

Memoir prepared by Chason W. Brooks, ASSOC. W. S. E., committee.

ABEL O. ANDERSON, M. W. S. E.

Died May 16, 1913.

Abel O. Anderson was born at Lake City, Iowa, December 7, 1881. He graduated from the Lake City High School in 1900, and from Iowa State College in 1906 with the degree of B. S. in Mining Engineering.

During his college career he designed and installed a telephone system for a town in Iowa, and made surveys, plans, and estimates for a short line of railway. During the winter months of 1906-7-8 he worked in the Chemical Section of the Engineering Experiment Station. During the corresponding summers he enjoyed a liberal private practice in general engineering work.

The change in the drainage laws about this time caused much work along drainage lines and Mr. Anderson handled practically all the county work in Sac, Calhoun, and Webster Counties for four years.

It was this experience that caused him, in 1910, to be selected as Assistant Engineer of the Civil Engineering Section of the Experiment Station, of the Iowa State College, because the station was, at this time, just establishing the last of four experimental drainage systems in the different parts of the State. In addition to this work he had charge of the local testing of materials sent in from over the State. This part of the work consisted mostly of testing cement and paving brick.

Soon after Mr. Anderson's arrival at the college special investigations along the line of improving the quality of tile drainage were started, and he turned his attention entirely to drainage matters. A year's experimental work with actual ditch and tile construction, including the weighing of pressures in ditches up to 30 feet in depth, and the breaking, in test, of several carloads of tile, resulted in the accumulation of data for a 180-page bulletin entitled "The Theory of Loads on Pipes in Ditches, and Tests of Cement and Clay Drain Tile and Sewer Pipe." The first copy of the bulletin came from the press just after Mr. Anderson's death and he had not the satisfaction of seeing the results of his labors.

He was a man fairly bristling with energy and ideas, and is daily missed in the laboratory and office.

He was a member of the American Society for Testing Materials, the National Association of Cement Users, the Iowa Cement Users' Association, Honorary Member, Interstate Cement Tile Manufacturers' Association, as well as a Member of the Western Society of Engineers.

Memoir prepared by C. A. Baughman, M.W.S.E., committee.

April, 1914

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS.

Extra Meeting, March 30, 1914.

An extra meeting of the Society (No. 857) was held Monday evening, March 30, 1914. This was a Ladies' Night. The meeting was called to order about 8 p. m. with about 140 ladies and gentlemen in attendance. Mr. Henry Schauffler and Mrs. George Colburn gave some instrumental music, and Mr. A. H. Andrews gave an interesting lecture on "The Cliff Dwellers," with stereopticon illustrations. After a little more music, the meeting adjourned, when refreshments were served.

Regular Meeting, April 6, 1914.

A regular meeting of the Society (No. 858) was held Monday evening, April 6, 1914. The meeting was called to order by President Lee at 7:45 p. m., with about 70 members and guests in attendance. The reading of the minutes of the previous meeting was omitted. The Secretary reported from the Board of Direction that at their meeting held that afternoon the following had applied for admission to the Society:

Shelby Sanfley Roberts, Chicago.
J. A. Stromberg, Chicago.
Theodore F. Laist, Chicago.
Philip J. Hickey, Chicago.
Hubert P. T. Matte, Oak Park, Ill.
Eugene Daniel Swift, Chicago.
Oswald A. Tislow, Detroit, Mich. (Transfer.)
Frank H. Drury, Chicago.
Eugene Gellona, Valparaiso, Ind.
William Everett Hartman, Chicago.
Charles Pope Howard, Chicago.
Quincy Allen Hall, Chicago.
Frederick E. Morrow, Chicago.

Also, that the following had been elected into the Society:

Earle Clifford Hazlett, Los Angeles, Cal.	Junior Member
Carl E. Brockhausen, Chicago	Member
Edward Cherrie Holden, Chicago	Junior Member
Francis H. Wright, Chicago	Member
James Sorenson, Milwaukee, Wis., transfer to	Junior Member
Charles A. Morse, Chicago	Member
Wm. O. Lichtner, Newton Highlands, Mass	Member

Mr. Andrews Allen was then introduced, who read his paper on "The Engineering Opportunities of our Coal Mining Fields." Discussion followed from President Lee and Messrs. W. C. Armstrong, W. C. Corl, Ernest McCullough, J. A. Garcia, R. G. Lawry, F. G. Vent, A. Reichmann, J. N. Hatch, Frank Rasmussen, and E. E. R. Tratman, with a written discussion from Mr. W. T. Curtis of Detroit, and a closure from Mr. Allen.

Meeting adjourned about 10:15 p. m., when coffee and sandwiches were served.

Extra Meeting, April 13, 1914.

An extra meeting of the Society (No. 859), the Bridge and Structural Section, was held Monday evening, April 13, 1914. The meeting was called to order at 7:40 p. m., by J. W. Musham, Vice-Chairman of the Section, with about 30 members and guests in attendance. Mr. B. J. Sweatt was introduced, who read his paper on Third Avenue Reinforced Concrete Bridge at Cedar Rapids, Iowa. This was illustrated by a number of stereopticon views. Discussion followed from Messrs. J. W. Musham, E. N. Layfield, H. C. Lothholz, I. F. Stern, W. S. Lacher, H. S. Baker, B. E. Grant, G. M. Mayer, C. C Saner, with answers and explanations by Mr Sweatt. A vote of thanks was tendered Mr. Sweatt for his paper.

Meeting adjourned at 8:40 p. m.

Extra Meeting, April 20, 1914.

An extra meeting of the Society (No. 860) was held Monday evening, April 20, 1914. The meeting was called to order at 7:55 p. m. by President Lee, with about 50 members and guests in attendance. The Secretary announced the deaths of Emil Gerber in Pittsburgh on April 16th, and of Past President Alfred Noble, in New York, April 19th. A motion was offered and passed that the President appoint committees to prepare memorials of these deceased members. Prof. H. H. Stoek was then introduced, who presented his paper, "Mining Laboratories of the University of Illinois." Stereopticon views were used in illustration. Discussion followed from Messrs. F. W. DeWolf, W. R. Roberts, H. N. Elmer, Andrews Allen, S. T. Smetters, with replies and explanations from Professor Stoek.

Meeting adjourned about 9:30 p. m.

Extra Meeting, April 27, 1914.

An extra meeting of the Society (No. 861), a joint meeting of the Electrical Section, W. S. E., and Chicago Section, A. I. E. E., was held Monday evening, April 27, 1914. The meeting was called to order at 8:10 p. m. by Mr. D. W. Roper, Chairman, with about 70 members and guests in attendance. The Chairman announced that at the next meeting in May there is to be an election of officers of the Chicago Section, A. I. E. E. Mr. W. B. Jackson offered a motion that a nominating committee be appointed by the Chairman to present at the next meeting, names of candidates for officers of the Section. Motion carried.

The Chairman then introduced Mr. F. G. Gasche, who read his paper, "Power Problems in the Steel Business." Discussion followed from Messrs. D. W. Roper, W. B. Jackson, H. H. Wait, T. Milton, E. W. Allen, W. Sykes, and O. H. West, with answers and explanations from Mr. Gasche. The Secretary offered a vote of thanks to the author for his interesting and valuable paper, which was carried.

Meeting adjourned about 9:40 p. m.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY.

IGNEOUS ROCKS.—By Joseph P. Iddings. John Wiley & Sons, New York. Cloth. 5½ by 9 in. Vol. I, pp. xi and 464, 1909; price $5.00. Vol. II, pp. xi and 685, 1913; price $6.00.

These two volumes are part of the same work as the author's well-known book on "Rock Minerals," and the three volumes form an exhaustive treatise—certainly the most complete in the English language —on the subject of igneous rocks, their composition, structure, relations, origin, etc.

The first volume of the work under review is devoted to the composition, texture, and classification of igneous rocks and has two parts, the first of which discusses the chemical and mineral composition of these rocks, while the second deals with nomenclature and classification. The latter subject is considered in detail and the "quantitative classification of igneous rocks" developed a few years ago by the author in collaboration with Messrs. Cross, Pirsson, and Washington, is explained. Volume II is concerned with a careful description of the different types of igneous rocks and with a discussion of their occurrence, especially their distribution in different parts of the world, with the view of laying a foundation for the study of possible petrographic provinces. Throughout the discussion, chemical analyses are used with great freedom.

These two volumes on igneous rocks represent the result of investigation and study of a long series of years by America's foremost petrographer, and they furnish a storehouse of information, as well as much food for thought and further study, to any one who will consult them. They are not, however, written for one who is unfamiliar with the elements of modern petrology. U. S. G.

INSPECTION OF CONCRETE CONSTRUCTION. By Jerome Cochran, B.S., C.E., M.C.E. Myron C. Clark Publishing Co., Chicago. 1914. Cloth; 6 by 9 in.; pp. 595+xiv; including index. Price, $4.00 net postpaid.

The book is divided into eleven successive chapters as follows: Inspection of Hydraulic Cement; Inspection of Sand, Stone and Miscellaneous Concrete Materials; Inspection of Proportioning and Mixing Concrete; Inspection of Forms, Molds, Centering and Falsework; Inspection of Steel Reinforcement; Inspection of Concreting; Inspection of Surface Finishes; Inspection of Waterproofing; Inspection of Concrete Sidewalk, Curb, and Pavement Construction; Inspection of Ornamental Concrete, Building Blocks, Posts, Ties, and Pipe; Inspection of Molding and Driving Concrete Piles.

The book is by all means the best book published for concrete inspectors and it was needed.

The design of structures is not touched upon.

The book could have been made more attractive and useful if the illustrations and photographs had been judiciously used. In its 600 pages there are but three or four small cuts.

It is unfortunate that the author felt obliged to repeat so much of the material under different headings, for one tires of reading apparently the same matter an indefinite number of times. Roughly speaking, it appears that the same amount of information could have been given with one-half the number of pages. The book is simply tiresome in endless repetitions.

There are various recommendations, of course, about which there is difference of opinion, with little allowance for advancement in the art. The energetic inspector, after reading the book, must not feel that he possesses knowledge of all methods and their results, and try to enforce his knowledge.

There are various things apparently omitted which it appears to the reviewer should have a place, and some methods suggested which are not common practice at least.

The book, however, aims at better concrete work and therefore should be commended. W. A. H.

DESIGNING AND DETAILING OF SIMPLE STEEL STRUCTURES. By Clyde T. Morris, M., Am. Soc. C. E., Professor of Structural Engineering, Ohio State University. 1914. Cloth. 6 by 9 in.; pp. 260; illustrated. Price, $2.25.

This book is the third edition, revised, enlarged, and reset. The following paragraph is the author's preface to his third edition:

"After four years' use in the class room, the author has decided that the arrangement of the chapters could be improved and as he wished to include some additional material in the book, he has taken this opportunity to change the order of presentation of the different topics. The whole book has received careful revision and several of the chapters have been partially rewritten. A new chapter on highway bridges has been added, together with a reprint of the Specifications for Steel Highway Bridges of the State Highway Department of Ohio. About half of the figures in the book have been redrawn and a number of new figures added and such errors as have been discovered in the text have been corrected."

A review of the first edition appeared in the 1910 volume of the Journal of this Society, and for the convenience of the reader it is quoted herewith:

"With the exception of occasional chapters in exhaustive treatises on bridge and structural engineering, there has been but little published dealing specifically with good practice and methods in designing and detailing of steel structures. The subject of stresses appears to be sufficiently covered. There is no lack of books on this subject, and it is a favorite study in all technical schools. But the art of producing 'details which are in accord with the stresses they have to transmit' has been practically overlooked, or left to be picked up by the engineer as best he may in practice. This work, therefore, fills a real need. It is written with the presumption that the reader is familiar with methods of calculating stresses, and little space is given to this subject.

"The book covers in detail riveting, roofs, plate-girder bridges and pin-connected bridges, and contains two general chapters on designing, estimating, manufacture, and erection. No claim is made to exhaustiveness in this treatment of the subject.

"The author advises keeping at hand, for reference, the larger standard works on bridge and structural engineering. But the work does attempt to supply, in compact form and in sufficient detail, just such information as the engineer or draftsman needs in his daily work. The success with which this is done suggests the idea that the book is the result of years of practice on the part of the author. The work as a whole is simply an outline of good practice as recognized by all competent designers.

"The general chapters on designing, estimating, manufacture, and erection contain much that is of value on office methods and equipment, and the ordering and handling of material, as well as information on shop work, inspection, and erection.

"The book is well adapted to the needs of both the engineer and the draftsman. J. E. M."

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts, the following publications have been received:

NEW BOOKS.

McGraw-Hill Book Co.:
- Designing and Detailing of Simple Steel Structures, Clyde T. Morris. Revised and Reset. Cloth.

MISCELLANEOUS GIFTS.

Robert H. Whitten:
- Fair Value for Rate Purposes, Whitten. Pam.
- Regulation of Public Service Companies in Great Britain, Whitten. Pam.

Metropolitan Sewerage Commission, New York:
- Preliminary Reports on Disposal of New York's Sewage, Nos. XI, XII, XIII, XIV, XV, XVI. Paper.

New Hampshire Public Service Commission:
- Report for Year 1913. Cloth.

H. M. Byllesby & Co.:
- Arbitration Proceedings, Indianapolis Traction Company and Employees. Pam.
- Proceedings, City Planning Conference, Chicago, 1913. Cloth.
- Report of Transit Commission, City of Philadelphia, 1913. 2 vols. Cloth.
- American Railway Number, London Times, June 28, 1912. Cloth.
- Reports of Progress of Stream Measurements in Canada, 1912. Pam.

Columbus, Ohio, Division of Water:
- Annual Report, 1913. Pam.

Sanitary Research Laboratory, Massachusetts Institute of Technology:
- Contributions, Vols. 4, 6, 7, 8, 9. 5 pams.

Daniel W. Mead, M.W.S.E.:
- The Present Status of the Water Powers of Wisconsin, Mead. Pam.

EXCHANGES.

National Paint Manufacturers' Association:
- Bulletin No. 41, The Toxic and Antiseptic Properties of Paints. Pam.

American Water Works Association:
- Proceedings, 1913. Cloth.

Canada Department of Mines (Geological Survey):
- Guide Books Nos. 5, 8, 9, 10. 6 pams.

Royal Philosophical Society of Glasgow:
- Proceedings, Vol. XLIV, 1912-13. Paper.

New Jersey State Board of Health:
- 36th Annual Report, 1912. Cloth.

Missouri Bureau of Geology and Mines:
- Biennial Report of State Geologist. Pam.
- Geology of the Rolla Triangle. Cloth.

American Institute of Consulting Engineers:
- Address by President Alfred Noble at Annual Meeting, Jan. 20, 1914. Pam.

Institution of Engineers and Shipbuilders in Scotland:
- Transactions, Vol. LVI, 1912-13. Cloth.

- Virginia Geological Survey:
  - Coal Resources and General Resources of the Pound Triangle. Pam.
- Idaho Society of Engineers:
  - Journal, June, 1913. Pam.
- Brookline, Mass., Water Board:
  - Annual Report, 1913. Pam.
- Engineering Association of the South:
  - Proceedings, Jan., Feb., Mar., 1914. Pam.
- American Society of Agricultural Engineers:
  - Transactions, St. Paul Meeting, Dec., 1911. Pam.

GOVERNMENT PUBLICATIONS.

- U. S. Bureau of Standards:
  - Scientific Paper No. 213, Critical Ranges A_2 and A_3 of Pure Iron. Pam.
- U. S. Bureau of the Census:
  - Mortality Statistics, 1912. Cloth.
  - Financial Statistics in Cities over 30,000 in 1912. Paper.
  - Insane and Feeble Minded in Institutions, 1910. Paper.
  - Paupers in Almshouses in 1910. Paper.
- U. S. Bureau of Mines:
  - Third Annual Report of Director, 1913. Pam.
  - Technical Papers Nos. 39, 58, 66, 69, 71. Pams.
  - Bulletins Nos. 42, 68. Pams.
  - Monthly Statement of Coal Mine Fatalities in United States, December, 1913. Pam.
- U. S. Geological Survey:
  - 78 Topographical Maps.
  - Fuel Briquetting in 1913. Pam.
- U. S. Coast and Geodetic Survey:
  - Results of Magnetic Observations, July 1, 1911, to Dec. 31, 1912. Paper.
  - Results of Observations at Sitka, Alaska, 1911 and 1912. Paper.

MEMBERSHIP

Change of Address.

Weber, Carl, President, Gun-Crete Company, 1029 McCormick Bldg., Chicago.

Additions.

Brockhausen, Carl E., Chicago	Member
Hazlett, Earle C., Los Angeles, Cal	Junior Member
Holden, Edward C., Chicago	Junior Member
Lichtner, Wm. O., Newton Highlands, Mass	Member
Morse, Charles A., Chicago	Member
Wright, Francis H., Chicago	Member

Transfers.

Sorenson, James, Milwaukee, Wis., Student to	Junior Member

Deaths.

Gerber, Emil, Pittsburgh, Pa., April 16, 1914.
Noble, Alfred, New York, N. Y., April 19, 1914.

VOL. XIX, No. 5. MAY, 1914

JUN 17 1914

JOURNAL
OF THE
WESTERN SOCIETY
OF
ENGINEERS

CONTENTS

The Engineering Opportunities of Our Coal Mining Fields.
Andrews Allen 413
Discussion:
By W. C. Armstrong, Ernest McCullough, John A. Garcia, Raymond G. Lawry, Albert Reichmann, F. G. Vent, James N. Hatch, W. F. Corl, E. H. Lee, E. E. R. Tratman, J. F. Hayford, W. T. Curtis, and the Author.
Mining Laboratories of the University of Illinois.
H. H. Stoek and E. A. Holbrook 459
Discussion:
By E. H. Lee, F. W. De Wolf, W. R. Roberts, Andrews Allen, S. T. Smetters, and the Author.
Power Problems in the Steel Business. F. G. Gasche 487
Discussion:
By D. W. Roper, Wm. B. Jackson, H. H. Wait, Taliaferro Milton, E. W. Allen, Wilfred Sykes, and the Author.

Public Utilities.

Government Regulation of Railroads from the Investor's Standpoint. Andrew Cooke 503
Valuation of Public Utilities from the Railway Point of View. Saumel O. Dunn 507
Public Utility Regulation from the Standpoint of the Public and the Engineer. Harold Almert 516
Discussion:
By Onward Bates, J. W. Alvord, Wm. D. Jackson, Shelby S. Roberts.
Proceedings of the Society, Minutes of Meetings 541
Book Reviews 543
Library Notes 547
Membership 548
Index to Advertisers XXII

CHICAGO

Published Monthly, Excepting July and August, by the Society,
1735 Monadnock Block.

Entered as Second-Class Matter March 3, 1896, at the Postoffice at Chicago, Ill., under Act of March 3, 1879.

Subscription Price, $3.00 per Volume of Ten Numbers.

50 Cents a Single Number.

Copyright, 1914, by the Western Society of Engineers.

WESTERN SOCIETY OF ENGINEERS

1735 Monadnock Block, Chicago, Illinois.
Phone Harrison 945.

OFFICERS FOR 1914.

President	E. H. Lee, Dearborn Station
First Vice-President	B. E. Grant, Room 207 City Hall
Second Vice-President	Ernest McCullough, 1302 Monadnock Block
Third Vice-President	G. F. Gebhardt, Armour Institute
Treasurer	C. R. Dart, Room 700, 900 Michigan Ave.
Trustee	J. G. Giaver, 1 year, 1417 Railway Exchange
Trustee	F. E. Davidson, 2 years, 1448 Monadnock Block
Trustee	H. S. Baker, 3 years, 402 City Hall

Past Presidents on the Board of Direction.

O. P. Chamberlain	108 So. La Salle St.
W. C. Armstrong	226 W. Jackson Blvd.
Albert Reichmann	72 W. Adams St.

ELECTRICAL SECTION

Executive Committee

F. J. Postel, Chairman; H. M. Wheeler, Vice-Chairman

G. T. Seely	1 year
P. B. Woodworth	2 years
E. W. Allen	3 years

BRIDGE AND STRUCTURAL SECTION

Executive Committee

J. H. Prior	Chairman
J. W. Musham	Vice-Chairman

E. N. Layfield H. C. Lothholz I. F. Stern

HYDRAULIC, SANITARY AND MUNICIPAL SECTION

Executive Committee

W. D. Gerber	Chairman
G. C. D. Lenth	Vice-Chairman

W. W. DeBerard Douglas Graham Langdon Pearse

Secretary............J. H. Warder

The Chanute Medals

The Board of Direction, W. S. E., desire to announce that the Octave Chanute Medals will be awarded for the most meritorious papers on Engineering subjects presented before this Society by members thereof during the year 1914.

Journal of the
Western Society of Engineers

VOL. XIX MAY, 1914 No. 5

THE ENGINEERING OPPORTUNITIES OF OUR COAL MINING FIELDS

ANDREWS ALLEN, M. W. S. E.

Presented April 6, 1914.

The demands of the coal mining industry cover many different lines of specialized engineering. The mining engineer, of course, carries the principal burden, for he it is who must devise and oversee the general scheme, locate the coal, and determine in advance the best method of development. He must plan the workings, get the output, and meet the thousand and one emergencies arising in daily operation. But in these days of large operations no mining engineer can possibly cover the ground alone. He must call on other specialists to give him the tools with which he works and the power to operate.

Structural engineering covers the design, construction, and maintenance of the various mining structures and buildings. Electrical engineering covers the generation, transmission, adaptation and use of electricity for mining purposes. Steam engineering (if we make this subdivision) covers the generation of power from coal and its transmission to the hoisting rope or the generator armature, and mechanical engineering covers the various mechanical processes for producing and preparing coal, taking it from the mine car and delivering it as a finished and marketable product, also the many problems of maintaining a perfect and efficient plant far from the base of supplies.

The special object of this paper is to call the attention of engineers in these lines to the great opportunities in mining construction work; also to present to the coal operator and to the mining engineer a brief summary of the results that good engineering may be expected to produce for them and to call their attention to the advantages of obtaining such services from professional engineering firms.

The conditions under which a coal mine is operated in this country are extremely severe and unusual.

First: An enormous bulk of fragile material must be handled very rapidly and with minimum breakage. A 4,000 ton we draw a long breath, that we must look again into the future. because the future inevitably has for us new problems—fresh and often different problems which we must be prepared to meet as they arise.

It has recently seemed desirable to the Chicago Real Estate Board, as representing many of the largest tax-paying interests of this city, that some sort of review might be had of our present river, harbor and sanitary situation, and particularly as to our sanitary problems, so that some sort of an outlook into the future might be had to show us clearly what we must do to take care of the coming population which we can see, or think we can see, is pressing upon us for sanitary protection.

Through the very public-spirited generosity of Mr. Henry H. Walker, of the Chicago Real Estate Board, whom we have the pleasure of having with us tonight, funds have been provided for the use of the River and Harbor Committee of the Chicago Real Estate Board for this purpose, and after careful consideration by that committee the distinguished gentlemen who are here tonight (and who have been at work for the last two weeks) have been selected to look over the situation and advise us as to these important matters.

In order to formulate the situation, the River and Harbor Committee of the Real Estate Board framed up a series of questions which it thought adequately presented the sanitary problems which are imminent in the city of Chicago and its environs in the near future. I do not know that all of you have had an opportunity to realize what those problems are, and perhaps it might interest you to hear the series of questions which we have had put to these gentlemen:

> 1. Assuming that all of the sewage and trade wastes of the Sanitary District are to be dealt with by a dilution flow of water from Lake Michigan, what is the proper ratio of dilution water to population for Chicago to count upon in the future?
>
> 2. Assuming that trade wastes and solids are to be separated from the sewage flow at intercepting sewer outlets and treated, what is the best location and method for such treatment, and what ratio of dilution flows to population in the main drainage channel may be safely allowed for proper purification of the effluent water after such treatment?
>
> 3. Is it the best course for the city to rely on full and complete treatment of the sewage from its outlying territory and the application of Lake Michigan flow to the sewage of the central districts of the city, or would it be better to partially purify all of the sewage by initial treatment by screens, or in tanks, or both, at a large number of stations throughout the district, leaving the diluting flow of water from Lake Michigan to complete the treatment?

4. Is it best to concentrate the sewage flow for partial treatment at one or two main stations or should it be collected in a larger number of small districts and dealt with in smaller installations?

5. To what extent is it desirable to purify sewage under our present conditions, in the view of the uses and conditions in the channels and rivers into which our drainage is now discharged?

6. To what extent is it desirable to construct branch dilution channels receiving at their upper ends dilution water in place of collecting and intercepting sewers reaching to the main channel?

7. To what extent has the dumping and spreading of dredgings from the river into the Lake proved to be dangerous to the purity of the water supply, and to what extent should it be limited?

8. What should be done to improve the sewage conditions in such specially objectionable districts as the South Branch, in the Stock Yards district, the West Fork and the North Branch in the factory district?

9. Should trade wastes be dealt with at private or public expense and how may they best be treated under the conditions here?

10. Assuming that the general government will limit the amount of water to be taken from the Great Lakes for Chicago Sanitary Purposes to 10,000 cu. ft. per second, what supplementary works will be necessary, how soon should they be begun, and what will be their approximate cost?

11. To what extent should reliance be had for a pure water supply upon the prevention of accidental pollution of the Lake by steamships and commerce carriers, or from the deposit of dredgings, and when should reliance be had upon the purification of the water supply by filtration, sterilization, or other purification methods?

12. Will a harbor on the Lake Front prove to be in any way a menace to our water supply as at present located, and derived, and if so, what steps can be taken to prevent the contamination of the water supply from that source?

I think we can well appreciate that these gentlemen have had something to think about during their stay at our lake-front hotels. One of them asked me rather diffidently the other day if they really were expected to answer every one of those questions completely, and I assured him that to some extent those questions were formulated, not because we expected complete answers from them at this time but in part because we wanted the public to realize that there is an important problem here and what that problem consists of. Undoubtedly answers to some of these questions can only be obtained after years of study and the co-operation of the city, the Health Department, and the Sanitary District, and the analytical and technical work which they have under way now. and should begin in the near future. But fundamentally these are the questions which must be solved, and these gentlemen who are with us tonight can bring to their solution resources of long experience in many ways and in widely differing localities.

Here in Chicago we have many and varied ideas. I counted up this afternoon some twenty-five different ideas which I have heard advanced in one way and another as to the various phases and the merits or demerits of this and that part of our sewage. drainage, water supply and river problems. And while I won't inflict them upon you, you doubtless could recall many of them.

Now, as to this future sanitary problem of Chicago, I think we all realize that there is found a great advantage in bringing in fresh minds, minds which have not been so close in touch with this proposition that any one phase of it would perhaps obscure the rest of it, as is sometimes the case with some of us who live here and who are in daily touch with all these questions. In a sort of half-formulative way we who are close to these problems gain opinions without really realizing that we are taking any particular stand. And so it seems to be highly desirable to go way outside of our own circle to obtain a clear perspective and bring in fresh minds that can review this whole situation and bring to it a long experience of a general character.

We have with us tonight as one of these specialists, a gentleman who has been very prominent in the study of the solution of the sewage disposal problem of the city of New York. I think it would be a surprise to many of our Western Society members to know that New York City has a sewage disposal problem. I know it was a surprise to me when it was first suggested to me. I always had recalled that great, broad harbor of New York and imagined. without much reflection, that the city of New York at least would never be troubled with sewage disposal problems. But they have been studying very carefully and very thoroughly such problems. and I think you will be interested to hear something about the work which they have been doing.

Dr. George A. Soper, who not only is a distinguished sanitarian but for the past nine years as President of the Metropolitan Sewerage Commission of New York has been carefully studying conditions there, is with us and I take pleasure in introducing him to you. Dr. Soper, will you kindly give us a few words?

Dr. George A. Soper: Mr. President and Members of the Western Society of Engineers:

It is with great pleasure that we come here tonight to meet with you and to express the appreciation which we feel for the cordial reception we have had ever since we came into your city.

About a week ago we appeared at a luncheon of the Chicago Real Estate Board, and it was agreed, before we arrived, that inasmuch as the others chose to regard me as the chairman of the board, it would be appropriate for me to speak on behalf of the party such words of return greeting as the occasion seemed to require. I, in the best form I knew, undertook the task. The others had explained that they were quite incapable of making an address suitable to the occasion. I knew that I was not capable, but because I wanted to be as polite as possible to the foreigners, I undertook the duty. Events showed that I should not undertake it again tonight. My colleagues are so abundantly able to speak for themselves that I have been, and you will be, delighted and convinced, as I was, that the task is very well placed in their own hands. At the same time, I cannot refrain from saying that as a board we have received the most courteous, generous attention everywhere. Every fact that we have asked for from every department, from every official, even opinions—which, perhaps in some cases, we should not have asked for—have been given us with an appearance of sincerity and openness which has left nothing to be desired on our part.

Mr. Alvord told you a joke, but only half of the joke. I refer to the list of questions which he said it would require years on the part of many to answer. The other part of the joke lies in about one ton of literature now in our rooms. Perhaps the questions and answers are all in the literature, but inasmuch as we have not mastered it, we feel a good deal of humility in undertaking to supply even such answers as an engineer feels justified in giving in a qualified, careful way.

Mr. Alvord has referred to my work in New York, and as some of the problems which we have been considering in Chicago correspond with some of the problems in New York, it has occurred to me that you might be interested to know how New York set about solving its sewage question.

The situation was different in this respect, that in New York there had been no investigation of the sewage question. There had been no agitation or public opinion upon the sewage problem. There had been no individual or coördinated action on the part of the city or state or government, or on the part of the various cities —and there are over eighty municipalities in the Metropolitan district—to dispose of their sewage in an acceptable way. The field was clear. The opportunity was without the slightest obstruction.

The investigation was undertaken at the instance of the state. The state of New York passed a bill requiring the City of New York to appoint a commission to consist of five men, three at least to be of recognized skill in sanitary engineering, and it authorized New York City to raise the funds to pay the bills. The act specified about a dozen questions of large and searching scope that the engineering board had to answer.

Very briefly, the questions related first to the sanitary condition of the harbor and its various immediate tributaries. The board was asked whether the methods of sewage disposal then existing were satisfactory, and if not, what should be done to make them so? Was it desirable for the many cities and towns within twenty miles of the New York City Hall to form an agreement as to the way in which they could best dispose of their sewage? Would it be better for the two states to coöperate? or would it be wise for one Metropolitan sewage district and commission to be formed to attend to the main drainage and sewage disposal problems of the locality?

The commission was appointed in 1906. Two years later it was reorganized. What I have to say of the methods and policies and results of the work dates from January, 1908. The commission has remained without change of personnel from 1908 up to the present time. The members are four engineers and one physician. The engineers are Charles Sooysmith, M. W. S. E., whom you recognize perhaps by name as an authority on foundations and other underground structures; James H. Fuertes, whom you will recognize as a man who has done a great deal of sanitary work, especially in sewage disposal and water purification; H. deB. Parsons, whose work in connection with refuse disposal has perhaps made him known to many in this room, and the speaker. The physician of the board is Linsly R. Williams, who has recently been appointed Deputy Commissioner of Health of the State of New York in a plan of reorganization by which the health activities of the Commonwealth are to be greatly extended.

The first work to be done by the commission was to investigate the conditions of sewage and sewage disposal which existed. The ground, as I said, had never been covered. It was not known where all the sewers discharged. In some cases it was not easily ascertainable. The results of the disposal of the sewage into the harbor and its tributaries had not been investigated by any health authority. There had been relatively little complaint, except in some quarters where the complaint had been insistent—complaint of nuisance, complaint of harm to health.

The commission undertook to bring together the statistics of sewage for the district within 20 miles of the New York City Hall. It undertook, by means of inspections, by means of floating laboratories, and otherwise, to make a thorough study of the results of the sewage discharges. The floating laboratories moved from one part of the harbor to another, analyzing the water chemically and bacteriologically, and collecting samples of deposits to analyze them microscopically and bacteriologically.

The idea in the very large amount of analytical work done was not to determine, as some persons at the time supposed, whether the water was polluted or not. The object was to obtain knowledge as to the circumstances under which the sewage discharged into the water was assimilated by the natural forces which existed there. It was recognized by the commission that the water had a great power for harmlessly assimilating the sewage materials, and it was considered desirable for reasons of economy to utilize the digestive or assimilative capacity to the full extent consistent with a due regard to the public health and welfare.

Estimates were made to determine what it would cost to carry all the sewage away from the harbor and dispose of it on land, dispose of it at sea, or dispose of it by intensive purification; but the cost in all cases was found to be prohibitive. It was recognized from the outset that disposal through dilution must be an essential feature of whatever method the city would adopt. It was recognized that the disposal of sewage through dilution had its limits. It was found that under certain circumstances very little sewage could be put into water without creating a nuisance.

I will not undertake to relate, even in outline, the other studies. They were very considerable. Experiments were made both in the laboratory and on a large scale in the field to determine under what circumstances sewage could be mixed with water, because it was found that the water would have to be thoroughly mixed with the sewage before the sewage ingredients would be assimilated.

The amount of dissolved oxygen in the water was at that time considered to be a matter of the utmost importance. Analyses of the water for dissolved oxygen were made at all seasons of the year, at all stages of the tide, in all parts of the harbor and at all depths. The analyses were made on the spot.

It was then regarded, and is still regarded by the Metropolitan Sewerage Commission, that the dissolved oxygen represents the best single criterion of the relative intensity of sewage pollution. But as the commission's work continued, the importance of the oxygen test seemed to be considerably diminished.

Very briefly, where the water of the harbor would have contained 100%, or its saturation value, of oxygen, if no sewage had been discharged into the water, it has been found that large arms of the harbor, as for example the East River from the Battery to Hell Gate, were depleted to the extent of 60 to 70%. During the work of the commission, extending over the years I have mentioned, there has been a progressive decline in the amount of oxygen present. Two summers ago samples were selected of the best water that could be had from the lower East River at the Brooklyn Bridge, and it was found that there was less than 20% of the saturation value of dissolved oxygen in it. The value of the oxygen test is minimized, in the view of the commission, by the presence of deposits on the bottom. There might be sufficient oxygen in the water to prevent putrefaction, but if the deposits on the bottom were in a putrefiable state, they would ferment, gas would be given off, offensive odors would be produced, large quantities of black mud would be distributed through the water, and other objectionable consequences would follow. Now, very briefly then, the commission found it necessary to make a thorough examination of the whole theory of the disposal of sewage through dilution.

Health was affected in various ways in the pollution of the harbor. The harbor was used for the cultivation of shell fish, and where shell fish were not actually put into the water for cultivation, wild shell fish were often taken. It has been estimated by the commission that over 500,000 bushels of oysters are taken from the waters within the city limits, and consumed for the most part in raw condition. There are over 800,000,000 gallons of sewage discharged every day into the waters. Over 3,000,000 baths are taken in floating pool bath establishments, into which and out of which the harbor water has free access. Many people are in constant touch with the water in their various vocations about the water front. Driftwood is taken by many people to their homes and used as fuel—dried in many cases behind kitchen stoves and handled by those who prepare the food for the family.

The commission, however, has not laid great stress upon the danger to health which the pollution of the water of the harbor represents. It has taken the ground that the discharge of sewage into the harbor, as at present, is an offense to the sense of common decency. Extensive investigations were made of the practices of other cities, particularly European cities, and it was found that most of them went to large expense to carry their sewage entirely out of the open waterways within their municipal limits. That was done—it was found upon inquiry—not as a measure of health alone, but by what one of my friends in Germany called "culture." He said, "You don't understand it in America, but we call it 'culture.'"

It would be impossible, as we found, for reasons of cost, to carry all the sewage away from New York Harbor, and, frankly, the commission considered that it was unnecessary to do so. The water must be polluted as gauged by a drinking water standard. Because it was polluted, it was rendered unsuitable for bathing and shell fish culture.

The question arose: How clean should the water be kept? What are the requirements of health and common decency which must be satisfied in any system of main drainage and sewage disposal to be built for the city? And at this point the commission followed a policy which has extended throughout all its work. It formulated its own ideas, put them in definite, written shape, and then called in a number of sanitary experts to make independent reports on the question. The commission throughout has secured the most competent criticism of its work which this country and Europe could afford.

There were eight sanitary experts called in to advise on the standard of cleanness for the water. I need not mention their vocations, probably, but there was a physician, a professor of hygiene, engineers—three engineers, I think, all of whom you would probably know if I mentioned them. And eventually the investigations made by the various experts were brought together, published individually, and a digest of their opinions published, with the commission's opinion.

Based on the standard of cleanness which the commission considers should be the goal in keeping the harbor reasonably clean, there were laid out main drainage and sewage disposal works for the city of New York. For that purpose the city was divided into four great areas or drainage districts. They were laid out, without reference to political lines, borough boundaries or anything of the kind, and with strict reference to the necessities of drainage and the opportunities of drainage.

Intercepting sewers and disposal works along various general lines were laid out for the different parts of the city. During the course of that work five experts were brought in. The total number of experts which the commission has called upon from time to time has been over twenty, and in every case their reports have been published, or are in preparation for the final report of the commission.

Very briefly, the plan of disposal recommended for the city of New York is the collection of the sewage at a number of central points where after more or less treatment the effluent will be discharged into the main tidal channels. You understand, of course, that the city is of great extent, and the opportunities for treatment works and for disposing of the effluent, vary in different places.

In a large number of cases—I think there are twenty-four or twenty-five—sewage would be brought to central points and screened, passed through grit chambers, and discharged through submerged outfalls laid on the bottom of the harbor at a distance not less than 200 ft. from the pierhead lines. In four principal cases there would be extensive sewage disposal works. They would consist of settling basins, which could in course of time be used as precipitation basins, and submerged outfalls. With the exception of one plant—not a large one—the commission has recommended disposal works of less efficiency than sprinkling filters or contact beds, for the reason that the more efficient the process the greater is the likelihood of odor.

The commission has not—and this after the most careful consideration—deemed it wise to recommend settling basins within the built-up parts of the city, because of the danger of nuisance and because of the popular objection which would certainly be aroused if the property holders in the neighborhood learned that sewage disposal works were going to be placed near them.

The policy of utilizing to the fullest extent practicable the assimilative capacity of the water should be carried out, but it will not be sufficient to answer the requirements for all time. The water will become over-burdened with sewage unless some of the sewage is taken away. Consequently the commission has recommended that about 200,000,000 gallons of sewage be taken from the innermost part of the harbor and disposed of at a distance.

New York is unfortunately situated in not having suitable land where the sewage can be taken for oxidizing treatment. It has been recommended that an island be built in the sea about three miles off the shore for the construction of settling basins where the

200,000,000 gallons of sewage will be taken and finally disposed of. There will be about 1,000 tons of sludge removed every day from that sewage. The sludge will be taken to sea by a tank steamer and dumped. The works, including intercepting sewers, pumping station, mains, island, tanks and submerged outfalls, will cost about $17,000,000.

There is a still larger plant of settling basins proposed for the junction of the Harlem River and the East River, where in course of time—a time not too far distant for engineers to reckon on—there will come about 400,000,000 gallons of sewage for disposal.

I have been speaking of the conditions of pollution as they exist today, but of course the works which are designed are to serve the future. It is expected that the population will double in thirty years. The quantity of sewage will more than double.

The works are laid out with the intention that they shall be built, not at once and as one enterprise, but in progressive stages. The steps have been definitely indicated. By 1920 about $25,000,000 will have been spent on the works; and by 1930, about $50,000,000. The commission has made comparatively few calculations beyond the year 1940.

The status of the commission is advisory. It has no power to construct; it has no power to compel the construction of works. It is expected, however, that this board, having been provided in the first instance by the state and being continued on three occasions by legislative acts passed at the instance of the city, the work paid for by the city and brought to its present point will be carried out in all its essential particulars.

From first to last the investigations have cost $263,000. The commission has two more years to serve, according to the last act of the legislature, but it has recommended its own extinction—said to be an unprecedented thing—because it has finished the work for which it was created. There is now before the city a comprehensive plan and policy for keeping the harbor reasonably clean, and, according to the legislative instructions, the commission has recommended the form of administration which in its judgment is best suited for the construction and maintenance of the main drainage and disposal works required. A special commission should be created to do the work.

Throughout the work the commission has enjoyed the coöperation of city officials, and the United States Government has coöperated in tidal and other studies. If the work is not of an authoritative character, the blame lies wholly with the commissioners themselves and largely with its president, who has had personal charge of all the scientific and technical work which has been done.

It is a peculiar pleasure to me to remember that at a time when the commission was considering the various alternative schemes for the reasonable protection of the lower East River against pollution, it called from Europe one of the distinguished Englishmen who is here tonight, Mr. Watson. It was largely as the result of his opinion, arrived at, I think, quite independently of the opinion of the commission—which we tried not to give him—that at least 200,000,000 gallons of sewage from the lower East River territory should be carried to sea. The commission had four alternative projects, and before deciding permanently which one to recommend, it called upon Mr. Watson to examine the conditions and advise which of the alternative schemes, if any, was satisfactory in his opinion, and if none of them would do, to recommend a more adequate and economic treatment of the question.

Mr. Alvord: About twenty-six years ago I started out on an exploration trip to find out, if I could, what sewage disposal plants were, and in the course of my peregrinations I landed in Birmingham, England. With the characteristic American assurance, and with the nerve of a somewhat earlier youth than I now possess, I walked into the office of the Chief Engineer of the Birmingham Sewage Works and presented my card, and asked him what he was doing and if I could see it. Fortunately I received a very courteous greeting and facilities were kindly placed at my disposal to look over the then existing plant, the city at that time being about to embark on a much larger project. I recall distinctly the appearance of the Chief Engineer whom I met at that time. I should say now that he seemed young. But he also looked as if he felt a great weight of responsibility on his shoulders. I have looked in vain for that youthful look since again meeting Mr. Watson here, but there is in its place a more mature and more convincing expression, though no more hopeful than I seem to recall twenty-six years ago.

Since that time Mr. Watson has carried out one of the largest and most successful sewage disposal propositions in England, that for the treatment of the sewage of Birmingham, and he has been called in, in many other places, to advise in projects of a like character. He has been recently elected and is now the honored president of the Sanitary Institute of Great Britain.

I am sure we shall be very glad to hear a few words from Mr. John D. Watson.

Mr. John D. Watson: Mr. Chairman and Gentlemen:

You make me blush for very shame at the manner in which you have greeted me, which is quite overpowering, and I frankly say that after the very eloquent address which you have listened to from Dr. Soper you have placed me in a very embarrassing position.

I say sometimes, and I say it with great feeling, that engineers are very bad speakers. But I think I will have to change my mind. Dr. Soper has given to you one of the clearest expositions of a sewage scheme, or a projected sewage scheme, that I think it has ever been my privilege to listen to. And I should like also to say that I never was called in to give advice in any single instance where more ample and more careful preparatory investigations had been made for the guidance of the expert than the case of New York under Dr. Soper's skillful lead.

We English engineers do not make the thorough investigations before we attack our problems that I found on this side of the Atlantic. I have been inculcating that disposition in England. I have been assuring my brethren that we are not as careful and as thorough in our investigations as we ought to be.

We sometimes forget that the very best work of that kind and the earliest which has ever been done was at Lawrence (Mass.). I remember very well that at the Congress of Hygiene and Demography, which was held in London in 1891, those of us who were interested in the disposal of sewage at that time—I can only speak for myself and for many friends with whom I have spoken since—passed by the investigations of the Massachusetts State Board of Health that were lying on the table. Those investigations indicated very clearly the lines upon which we are working today. But, as I say, we then passed them by.

Since that time, however, we have had occasion to admire and to follow the lines indicated. And perhaps we have done so more boldly, more thoroughly than any other people. The reason was obvious. Professor Whittle put it very graphically and very accurately when he said that the reason why England has taken the lead in the matter of sewage disposal was because necessity was the mother of invention.

The English rivers are small. The cities are large. Hence the absolute need to purify sewage. In some cases our rivers were so filthy that they looked more like ink than water. The odor emanating from them was so great that injury to health was manifest; injury to health was so apparent that committees intrusted with the care of the public health had no difficulty whatever in persuading their constituents of the need of that work and had comparatively little difficulty in getting money to do it.

Early in the history of sewage purification as we know it now, I was called in to advise what should be done at Balmoral Castle. I recommended what I believed then, and what I believed for long after, to be the very best method of disposal of the sewage. I advised irrigation, but Queen Victoria would have none of it. She said, "No, we are not going to have any irrigation here near my castle." And something else had to be substituted. Another process was adopted, which was comparatively successful, but it certainly did not purify the effluent to the extent that it ought to have been purified considering the fact that the effluent was discharged directly into the river from which the citizens of Aberdeen drew their drinking water. But then, the sewage was from a Royal Castle!

We have traveled a long way since then, gentlemen. Irrigation is as good a way of purifying sewage as any in existence. It is perhaps better than any. You get more equal effluents from a good irrigation field than from any other purification process. But still those effluents are not invariably free from pathogenic organisms.

That, however, has not been the reason why irrigation has ceased to be so popular in England. The reason is rather that so much land is needed; the area required in the case of a large town is very great. In the case of Birmingham where I have been bold enough to advise the disuse of miles of territory as irrigation fields for the purification of sewage and to substitute biological filters, the reason for the change was chiefly this, that it required the addition of an acre of land *every week* in order to keep pace with the growing population.

Now, Birmingham is not a great city in the sense that some cities are great. Birmingham and the immediate district which forms the constituent authorities of the drainage board, has a population of only 1,000,000. Paris is much greater and there the same difficulties obtain. Dr. Cailmette, in the recent report which he has sent to the Minister of the Interior, states very distinctly that in the future they must extend their purification works, not by enlarging their irrigation farms, but by erecting biological filters. And he recommends that this should be done on the lines which have been adopted at Birmingham, which I ought to tell you were gradual. There was no drastic movement. In the case of Birmingham, biological filters were built in order to meet the wants of the increasing population in the first instance, but we found that an acre of bacteria beds was equal to about 70 acres of land; and that we were able to concentrate the work on a very limited area. We were able to direct administration much more frugally, and were able to locate whatever nuisance is attachable to a sewage purification plant to this particular concentrated area. The drainage board wished to substitute biological filters for land as quickly as possible.

I have not given you the speech which I suggested to myself when Dr. Soper was speaking. I have quite a lot here which has no reference to sewage purification whatever. And I am not going to inflict that speech upon you now. But inasmuch as I have begun on the question of sewage purification, I should like to say that we are dealing with a subject which is practically new to this generation, and the public should be lenient with us if we make mistakes. Several generations ago the Craigenterry Meadows of Edinburg were used as irrigation meadows, but not for the purification of sewage. The meadows were never used for the purification of sewage as we understand the subject today, but merely for the purpose of passing over the land a liquid which was charged with organic matter for the purpose of raising crops. They were able to raise as many as six and seven crops of grass in a year, and that was the object they had in view at that time, rather than the purification of sewage. But, as I say, the subject which we are dealing with is a perfectly new one to this generation, and I think I am right in suggesting that the subject as we understand it originated with the State Board of Health of Massachusetts.

We have, however, gone through many vicissitudes in the study of biological purification. A good many of us have been engaged fighting terrible battles from that day to this. At one time we believed that the septic tank was going to get rid entirely of our sludge. Some of us believed it and acted upon it and constructed works with the idea that the septic process was going to liquefy all the sludge that went into the tank. But the day of reckoning came. We found that the septic tank had been over-rated and that some of us claimed for it what it was not able to do. Then we began to discuss the question of whether a percolation filter or a contact bed was the right method of considering the liquid portion of sewage. Then more recently we came to the stage of considering whether better forms of septic tanks could not be used.

My friend, Dr. Travis, of Hampton, inaugurated what was called the Hampton theory. He constructed a hydrolithic tank, and since that time Dr. Imhoff, of Essen, constructed a tank which was a considerable improvement on that which was designed by Dr. Travis. The Imhoff tank is an excellent one and it deserves its popularity.

In 1901 I began to study the question of intensive treatment of sludge, treating the sludge septically apart from the liquid, as is done by the Imhoff tank. I tried it for a whole year, but I am bound to admit I did not succeed. Since that time and since developments have taken place in the Emscher district, I have been using shallow tanks for the purpose of promoting fermentation of sludge, and we have been successful. Instead of constructing the deep, double-decked tank, as some one has called it, our tanks at Birmingham are quite shallow,—only 6 ft. deep. We pump sludge from one tank into another; that is to say, from the sedimentation tank into the sludge digestion tank. We help fermentation by injecting steam into the sludge as it passes along from the suction pipe through the pump into the delivery pipe. And in that way we have been able to raise the temperature 10 deg., promote putrefaction in raw sludge very quickly, and sustain fermentation in a very remarkable manner. Personally, I think it is cheaper, and sometimes better than the double-decked tank system. But, of course, circumstances must regulate whether an engineer adopts one method, or another, or a combination of both. Those things have all to be taken into account and must all go together if a complete system is to be installed which is capable of obtaining a uniform amount of suspended solids from sedimentation tanks, irrespective of velocity of flow.

I have found the drying of fermented sludge a burden, and have further found it necessary to accumulate mountains—I might call them—of inert sludge, sludge which is absolutely without smell and, therefore, without nuisance even. The weather does not affect it after it has been thoroughly dried, but I am faced with this difficulty, that I have a great big mountain of material which I cannot regard as being of any use at all. So I feel that while that is the case, there is something still to learn,—something which we must do.

We have a large amount of organic matter lying there doing nothing, organic matter which contains nitrogenous substances which might be utilized, and which, in my opinion, will be utilized. And if some of us only succeed in utilizing that material, which at present is going to waste, we will do what Sir William Crookes, the President of the British Association for the Advancement of Science, predicted some years ago in his presidential address, namely, be able to husband the nitrogenous matters which at present are wilfully thrown to waste, nitrogenous matter which is required so much for the production of fertilizing substances.

I do not know whether we all realize that before very long it will be necessary to find fertilizers if we are to carry on the business of agriculturists. But we must realize that the chief industry is agriculture; it is so both in England and America, indeed, in every country of the world, and before very long we shall find that we cannot get manure from our streets as we did formerly, the motor cars are taking the place of horses, and it would seem that we are going to find that there is a great dearth of mineral for fertilizing the land.

You are well aware that many farmers are leaving the States to go to Canada. Why? It is not that they are not satisfied with their citizenship, but it is because they find that the land is becoming less able to produce a crop which will pay for the labor which is put on the land. Without fertilizing substances, it is impossible to continue to produce good crops, and they have gone across the border into Canada where they have found the land in the state in which they first found it when they began to cultivate it in this country.

Now gentlemen, I should like to say this, I come here with great pleasure. I have great admiration for the American engineers. I now have the pleasure of knowing a good many of them, and I am a great admirer of the work which they have done. The best possible compliment which I could possibly pay you is this, that after my son graduated as a civil engineer at the Birmingham University, and after he had gone through certain work with an old assistant of mine at Leeds, a most excellent sewerage engineer, Mr. G. A. Hart, I advised him to come to the States, and he is now in the States, learning something of your untrammeled methods of getting directly to the object which you have in view. We are too conservative in the old country. We are sometimes too much inclined to follow precedent and to follow formulæ with mathematical accuracy. We want more of the characteristics which you have shown to the world to be inestimable.

Gentlemen, I thank you for the opportunity you have given me of coming here and being able to speak to so many, privately, and for this opportunity to say a few words to you collectively.

Mr. Alvord: It is not so very many years ago that those of you who are at all interested in sanitary matters can remember that there was wafted over this country those mystic words "The septic tank." The very distinguished gentleman who is with us tonight was on the spot where the septic tank was born, and if I am correctly informed, assisted in the studies which were made upon the original installation at Exeter, later became a partner of Mr. Cameron, its originator, and still later compiled a most useful book with which we sanitary engineers are all familiar, which is, as Dr. Soper has happily expressed it, packed full of facts on sewage purification work.

I take pleasure in introducing to you Mr. Arthur J. Martin, Consulting Sanitary Engineer of London and past president of the British Sanitary Institute. We shall have the pleasure of hearing a few words from him.

Mr. Arthur J. Martin: Mr. President and Gentlemen: I do not think I should be far wrong, if I were to say that this is the most embarrassing moment of my life. I am quite sure that you will understand and sympathize with me when I say that it will be mighty hard scratching for me to find anything to say to you after the two very able and interesting addresses to which we have just listened.

When I strike a good line, I always believe in sticking to it. I do not think I ever succeeded so well in putting an audience in good humor, as I did the other day by a chance reference to Michigan Avenue. I don't know how it was, but the words seemed to arouse recollections—pleasant recollections they must have been—in the breasts of those whom I was addressing. And so I don't think I can do better than to pronounce the same mystic words tonight.

Now the impression that Michigan Avenue made on me was that the people of Chicago knew a good thing when they saw it. They know what is best in architecture and in decoration, and they are not content with anything short of the best. And the moral I drew from it was that although down to the present time Chicago has not devoted so much attention as has been done in some other places to certain amenities of life, as with regard for instance to the disposal of refuse, and the appearance—I won't say the purity—of its water supply, and to such little matters as Bubbly Creek, yet when Chicago does take those problems in hand seriously, she will tackle them with the same energy, the same self-reliance, and the same capacity as she has tackled other great problems which she has encountered in the course of her short existence.

Those gentlemen present who are engaged in sanitary work will, I am sure, agree with me when I say that sewage disposal is one of the most elusive and many-sided problems with which an engineer can have to deal. Thirty years ago I knew all about it: twenty years ago I was not quite so sure; ten years ago I realized painfully that there was a great deal, a very great deal which I had yet to learn, and I have not yet done learning.

Now, I do not think my experience is peculiar to myself. I think it is simply a reflection of the transition through which opinion has passed, certainly in England, probably in other countries of the world, in which sewage disposal problems had to be settled. We began with an overweening confidence in the ability of land to deal effectually and speedily with all sorts of offensive matter. From that, as Mr. Watson has just told you, we passed on to have an equally enthusiastic confidence in the powers of the septic tank, in spite of the express warnings which were given by Mr. Cameron at the time he introduced the tank. I do not know that any of you care to go back to ancient history, but if so, if you will study some of Mr. Cameron's earliest statements with regard to the septic tank, you will find that, probably on account of his being a Scotchman and therefore gifted by Nature with a great amount of cannyness, he did not indulge in any rash predictions as to what the tank would do. And you will find that his statements with regard to the work done in the septic tank have been fully borne out by the findings of the Royal Commission on Sewage Disposal.

Again and again I have been at meetings where we have been assured that the contact bed was dead, and mine has been the solitary voice in the wilderness pointing out that the contact bed possibly had a career of usefulness before it yet.

Another vexed question is that of the standards to which sewage effluents should conform. Our work in England has been greatly handicapped by the assumption—it was not put in so many words, but it was the assumption on which we seemed to act—that sewage is the same thing all over the world, all over the country, at all events, and that the same rules with regard to capacity of tanks, size of filters, etc., should be applied in every case, and not only that, but that the same quality of effluent should be called for, no matter whether the effluent went into a trout stream or whether it was discharged into the estuary of a great river. Well, that kind of thing has, to some extent, died a natural death. But it is no exaggeration to say that in some cases urgently needed works of sewage disposal were hung up for years by the insistence of the Local Government Board on the provision of land for irrigation, in situations in which land was absolutely non-existent.

Now again we have received from the Royal Commission on Sewage Disposal a very excellent set of suggestions as to the capacities of works, but there is a grave danger that those suggestions will be crystallized into hard and fast rules, so that the design of a sewage works will be nothing more than a problem to be solved by certain mathematical formulæ.

I do not think that in this country there is any danger of sewage disposal practice drifting into such a position, but if so I hope this English experience will serve to warn you.

Now, out of the experience which I have had in dealing with sewage, there is only one rule which I recognize as of universal application, and that is to treat every case according to its merits.

In coming here, I resolutely divested myself of all preconceptions based on my English or my European or my Australian work, and made up my mind that I would look at this matter from an absolutely fresh point of view, and without reference to any work which I had carried out in any other part of the world. I come here, and I find an idea holding the field to a great extent, the idea of disposal by dilution. The situation of Chicago is, I think, unique, and an opportunity presented itself of which your engineers, with great daring and originality availed themselves, and with a considerable measure of success. Recently, I believe, doubt has been raised as to whether even this process of disposal by dilution might not have its limits. If I were talking to an audience in England, I should certainly warn them against the danger that the pendulum might swing too far in the opposite direction. I don't think I need to do so here.

During my stay in Chicago I have been impressed by the generous way in which a very large number of exceedingly busy men in the office of the Sanitary District, and elsewhere, have come to our aid and furnished us with a mass—an overwhelming mass—of data, and have answered the flood of questions which we have had in the course of our duty to pour upon them. I have met with a good deal of kindness in Canada and Australia and in other parts of the world, but I have never met with greater courtesy or kindness on the part of my professional brethren than I have met with here in Chicago.

With regard to what is expected of us, I am reminded of a certain reviewer passing judgment on a certain book which was submitted to him. He said that it contained a great deal that was new and a great deal that was true, but the things that were new were not true and the things that were true were not new.

Now, I trust that it is not expected of my colleagues and myself that we should come forward with any novel or startling proposition with regard to the treatment of the sewage of the city. If we did so, I think we should effectually blast our professional reputations. I rather think that what is expected of us is that, coming with fresh minds to this problem, we should endeavor to set things in their right focus and in their true proportion, and that possibly we should, through the opportunities which present themselves to us, do something to educate public opinion, at all events the opinion which counts, on behalf of those who are already working so strenuously in this great task.

Before sitting down—I have talked too long already, but I do want to associate myself most cordially with what Mr. Watson has said with respect to American engineers and American methods. I know very well that anything that savors of flattery or compliment would be distasteful, and I ask you to believe me that nothing of the kind is in my mind, and that I am simply speaking from the depths of full conviction when I say that we in England, working in a somewhat constricted environment, working amid obstacles of various kinds, some inherent to the situation, some due to our own temperament, working possibly with a slavish regard for precedent.

can and do admire and envy the way in which problems—engineering problems, and problems of many other kinds—are approached in this country. You may possibly have a little to learn from us in England; certainly we in England have a great deal to learn from America, more particularly as regards the direct and practical way in which you tackle your great problems.

I have greatly enjoyed the opportunity of meeting members of the Western Society of Engineers, and I shall carry back to England with me an account of the live engineering societies which you have in America.

Mr. Alvord: Engineers have a warm place in their hearts for the laymen that appreciate engineering work. I want to bear tribute to the public spirit and generosity of Mr. Henry H. Walker, who has made possible this investigation. Mr. Walker has traveled all over Europe and has, I think I may safely say, been to more sewage disposal plants and investigated them more often than any American sanitary engineer that I happen to know. We would like to have, before we close the meeting, a word of greeting from Mr. Walker.

Mr. Henry H. Walker: I have written on this subject many times, but I brought these gentlemen here to speak for me and indorse, I hope, some of the things that I have advocated.

CHARACTERISTIC CURVES OF CENTRIFUGAL PUMPS

F. WILLIAM GREVE, JR.,* ASSOC. W. S. E.

Presented June 1, 1914.

The development of characteristic curves, illustrating the performance of centrifugal pumps, provides a clear and precise method of comparing the relative values of such pumps.

Characteristic curves may deal with either the design or the performance of a machine, limited only in that the curves must be characteristic of that type and follow the same general equation for any one type of machine, irrespective of size or make.

It is not the purpose of this paper to cover questions of design or actual results that have been obtained, but rather to illustrate a characteristic method of diagramming the experimental data pertaining to centrifugal pumps. The accompanying diagrams were developed from data, chosen at random from a number of tests, to illustrate average conditions. The curves deal with the head, speed, capacity, horse power input and output, and the efficiency of a 4 in. centrifugal pump. The horse power output of the motor driving the pump is labeled b. hp. on the diagrams and was assumed equal to the horse power input of the pump, no allowance being made for belt slippage.

DIAGRAM NO. 1.

Three series of curves have been plotted on Diagram No. 1. At present, we shall consider only the set showing the relation between head in feet and capacity in gallons per minute, the speed remaining constant for any one curve. As one might expect, the head decreases with increase of capacity (except with very small discharges), but the curves show that the maximum head does not occur at the minimum discharge, but at a point equal to about one-third of the maximum. Had these curves been continued, they would have dropped on a line approaching the vertical. From the fact that the curves are parallel or concentric, the relations of head and capacity can be easily established by simply sketching in a new curve for the desired speed, the curves established from the test data acting as guides.

DIAGRAM NO. 2.

Diagram No. 2 illustrates the changes in efficiency for various values of capacity when computed for a constant speed. Up to a certain limit, variable for each size or make of pump, the maximum efficiency and capacity are found to increase with an increase of speed. It may be noted that the point of maximum efficiency moves to the right or to a point of greater capacity, as the speed is increased.

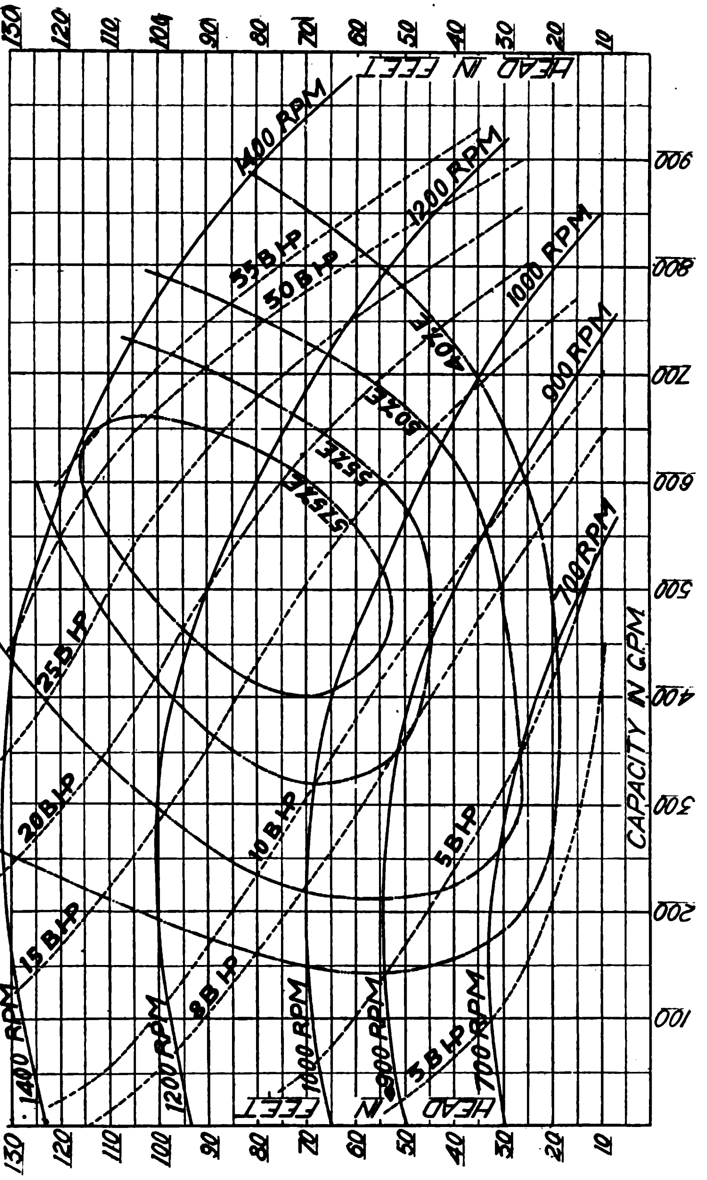
---

*Instructor in Hydraulics, Purdue University.

4" CENTRIFUGAL PUMP

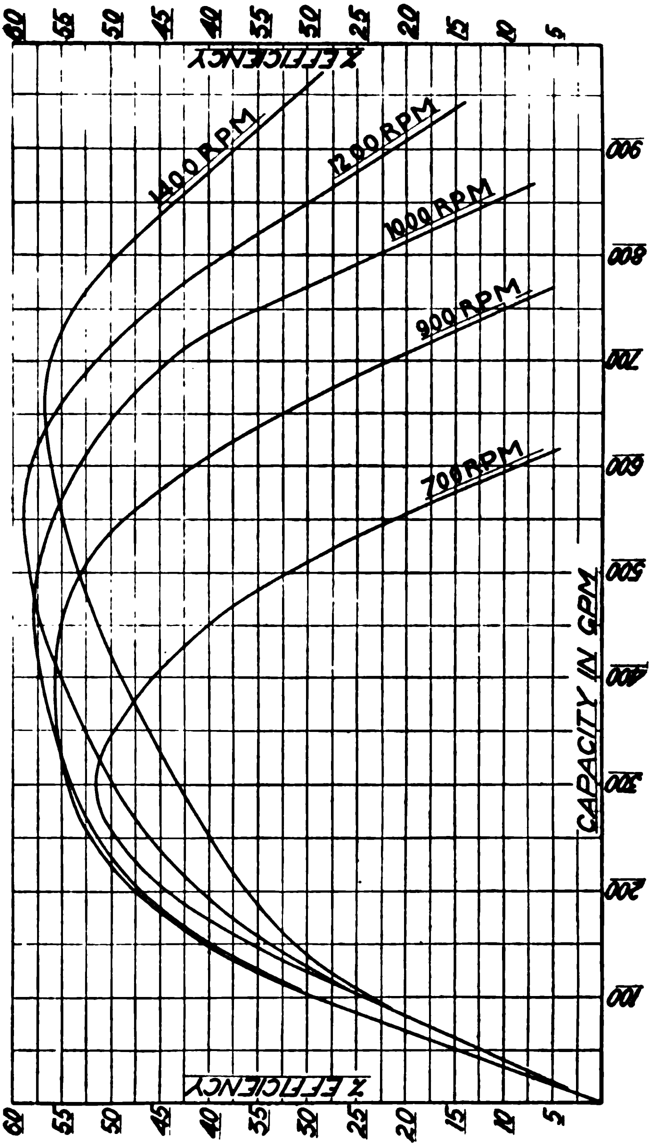
CAPACITY-HEAD~ISO-EFFICIENCY-B.H.P. CURVES NO. 1

CONSTANT SPEED



NO 2

4" CENTRIFUGAL PUMP
CAPACITY-EFFICIENCY CURVES
CONSTANT SPEED



For small discharges, the efficiency is practically the same at any speed. In general, each one of these curves resembles a semi-ellipse with the line of abscissae, or the capacity-line, as the minor axis. On this diagram, a maximum efficiency of 58% is obtained at a speed of 1200 r. p. m. and not at the highest speed.

DIAGRAM NO. 3.

The amount of horse power supplied to a pump to give a definite discharge at a constant speed, is shown on Diagram No. 3. As one might surmise, the horse power input increases with the discharge for a given speed until the point of maximum capacity has been reached, when the curve becomes horizontal.

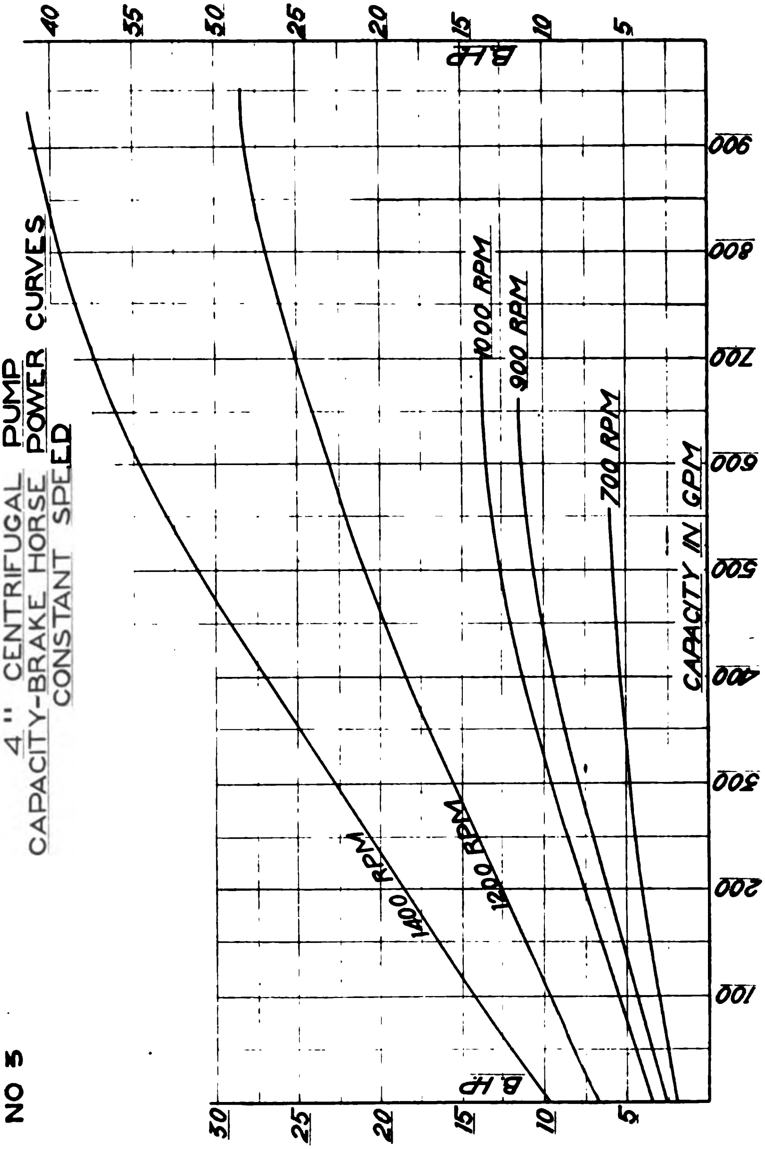
DIAGRAM NO. 4.

The curves on Diagram No. 4 have been plotted between brake horse power and revolutions per minute, the capacity remaining constant for any one test. Naturally, the input increases with the speed. These curves have been developed with the aid of Diagram No. 3. On the latter diagram the brake horse power has been read to give a constant discharge for the several speeds as plotted.

DIAGRAM NO. 5.

Curves determining the range in head for various speeds (the discharge remaining constant), are shown on Diagram No. 5, which was developed from No. 1 in much the same manner as Diagram No. 4 was obtained from No. 3. The equations of the curves follow closely those of straight lines, and indeed for large quantities may be assumed as such. This diagram and the one preceding it are not of great importance by themselves, but are valuable in determining the curves on Diagram No. 1.

Referring to Diagram No. 1, the series of curves drawn from the upper-left to the lower-right end of the sheet show the horse power required to discharge any quantity of water against any head and at any speed within the limits of the pump. The method of determining these curves is illustrated by the following: On Diagram No. 4 let us locate the point of intersection of the lines of 700 r. p. m. and 5 b. hp. The capacity by interpolation will be found to be 340 g. p. m. At the intersection of the lines of 900 r. p. m. and 5 b. hp. the capacity closely approximates 145 g. p. m. Repeat to secure several values of discharge and speed for the given horse power. On Diagram No. 4, the three lines of capacity, speed and discharge may be found to average at one point and then no interpolation is necessary. It may be well to remember that interpolation may be made of either the speed or the capacity, the horse power alone remaining fixed. Transpose to Diagram No. 1 the values of discharge and speed for the given horse power. Here again interpolation may be necessary. Connect the several points of equal horse power on Diagram No. 1 and the result is a curve showing the power required under various conditions of speed, capacity, and

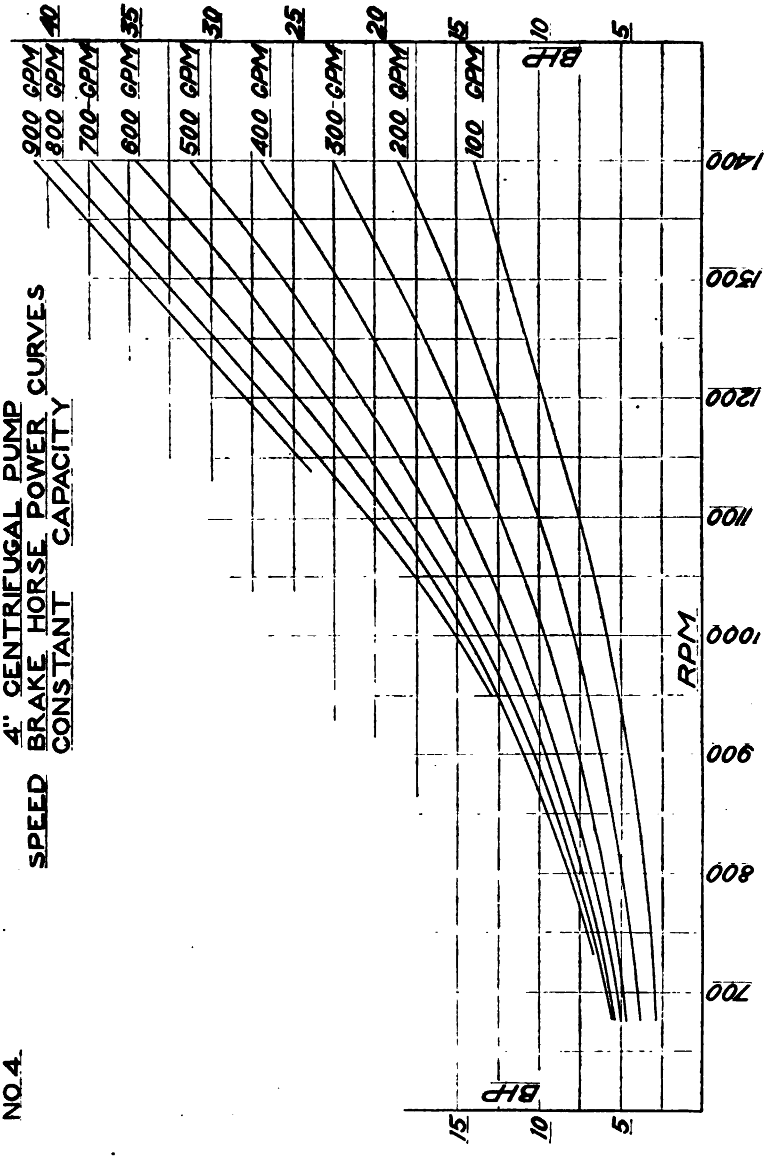


4" CENTRIFUGAL PUMP
CAPACITY-BRAKE HORSE POWER CURVES
CONSTANT SPEED

NO 5

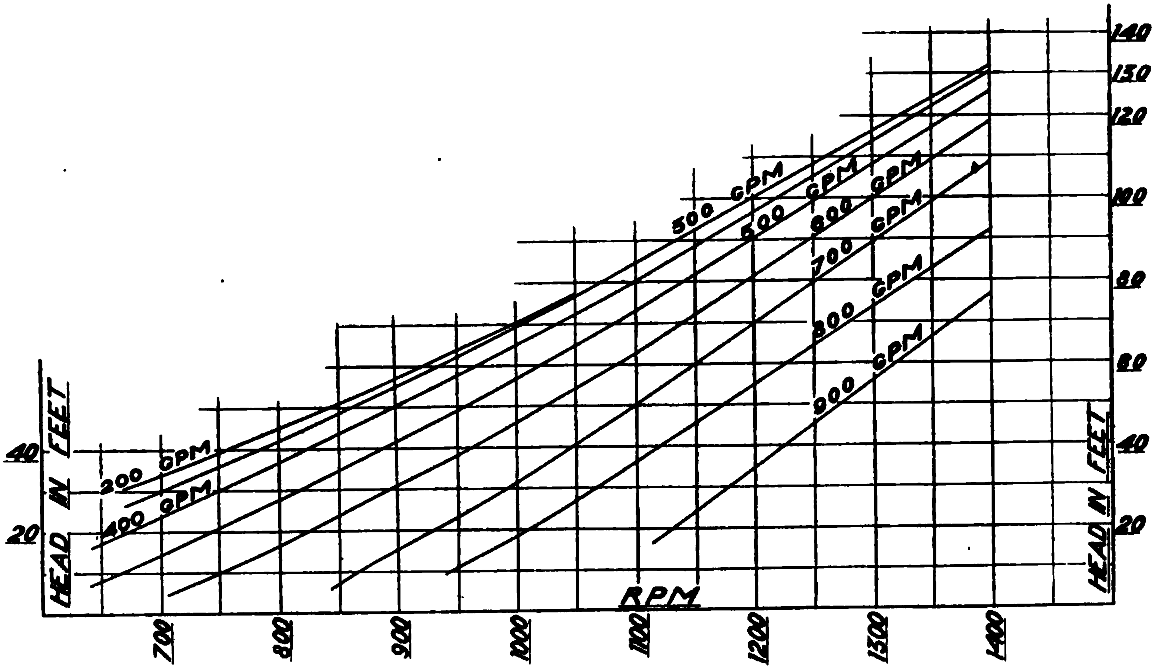
NO. 4.

4" CENTRIFUGAL PUMP
SPEED BRAKE HORSE POWER CURVES
CONSTANT CAPACITY



NO 5

4" CENTRIFUGAL PUMP
HEAD SPEED CURVES
CONSTANT CAPACITY



head. In the same manner, curves of any power within the requirements of the pump may be drawn. These curves are nearly parallel, or concentric, when the range in horse power is small. This fact is of great importance, for when the power is required for which no curves have been drawn, a new curve may be sketched in with reasonable accuracy.

In the general direction from the upper-right towards the lower-left side of the diagram, are shown a series of curves representing the efficiencies. In a manner similar to that employed in obtaining Diagrams Nos. 4 and 5, a series of curves could be plotted between efficiency and speed for any constant capacity. This is not necessary, because all the data needed are available on Diagrams Nos. 1 and 2. On Diagram No. 2 the line of 40% efficiency will be found to cross the line of 1,000 r. p. m. at the points of 150 and 700 g. p. m. Transpose these points of intersection of the lines of speed and capacity to Diagram No. 1, making use of all the speed curves drawn. Connecting the points of equal efficiency results in an Iso-Efficiency curve, or, in other words, a curve which shows the relations of head, speed, capacity, and horse power required to give a definite efficiency. When by this method an insufficient number of points have been plotted, or it is desired to check the results obtained, recourse may be had to Diagram No. 1. For instance, assume any point on one of the horse power curves. The head and discharge can be read immediately, and by the aid of these two quantities the horse power output of the pump is readily obtained. This pump horse power divided by the horse power input at the same point will give the efficiency at this point. Just as in drawing contour maps, it is possible to plot any number of these points. For example, a head of 61 ft. with a corresponding discharge of 559 g. p. m. results in 8.6 h. p. of work done by the pump. The horse power input is 15 and the efficiency is found equal to 57.5%. With a head of 82 ft. and a capacity of 416 g. p. m., the horse power is 8.6, the horse power input is 15, again resulting in an efficiency of 57.5%.

The efficiency curves are similar to the ellipse. The major and minor axii of each curve intersect in a common point, or origin, about which the curves themselves are concentric. This point of intersection is also the point of maximum efficiency. Similar to the discussion of the brake horse power curves, the fact that these Iso-Efficiency curves are concentric is very important. Efficiency curves which have not already been drawn can be sketched in with considerable ease and accuracy.

The advantages of representing the performance of a pump in the manner explained are several in number and are of interest to both the engineer and the manufacturer. The most valuable fact brought out in the preceding explanation is that in any series of curves on Diagram No. 1 the curves are parallel or nearly so. Diagrams Nos. 2, 3, 4 and 5 may be considered as supplementary to Diagram No. 1. Any question referring to the relations of speed, discharge, head pumped against, horse power input and output are quickly answered by reference to Diagram No. 1. In short, this diagram represents a map upon which the characteristics of the pump are indicated. It is the only one that is necessary to keep on file, thus reducing the amount of data to keep for reference. At the conclusion of a test, it is sufficient in itself in indicating the results obtained.

When more than one diagram is used in representing test results there is danger of error when the eye is deflected from one diagram to another. Tables are often prepared in lieu of diagrams which also give rise to error due to necessary interpolation and to the comparison of results, summed up under several headings. A salesman on the road is able to answer quickly and accurately the questions of a client in regard to the size and speed of a pump to discharge the required amount of water under given conditions and the efficiency of the machine under such conditions.

In conclusion, the characteristic curves explained illustrate the results of a test in concise form; reduce the liability of error to a minimum; require the least amount of data to be kept on file or forwarded to a prospective buyer; and provide an easy method of comparison of various pumps.

DISCUSSION.

President Lee: The paper is now open for discussion, and I am sure that Professor Greve will be glad to answer any questions that may be asked.

H. S. Bowen, M. W. S. E.: Have you found that you get the same characteristics for a specific total head, irrespective of how that total head is divided between discharge and suction heads?

The Author: We have noted some characteristics. The practical range was really the same. The range of suction in comparison with discharge is small.

Mr. Bowen: About what was the comparison of suction and discharge heads?

The Author: Where head is as low as 40 ft., the suction is probably 10 ft. As I remember, the characteristics came out just alike all through.

Mr. Bowen: Some recent tests indicated that there was quite a change in characteristics when the pump had a very low suction head without a foot valve, and when compared with the suction head was higher due to a foot valve. In either case the total head was low, about 12 ft., and the suction was a comparatively large per cent.

The Author: I did not work it out as low as that. Data seem to be more or less at fault. That is, in a great many tests the pump has not been credited with creating velocity. This does not seem to be fair.

S. T. Smetters, M. W. S. E.: Manufacturers' claims are much higher than the figures generally given for velocity of approach and velocity of discharge.

The Author: The velocity of approach and the velocity of discharge were obtained with the aid of the formula, $q=a\ v$; where q is the discharge in cubic feet per second, a is the area of the pipe in square feet, and v is the velocity in feet per second. The velocity of approach was very small except in the cases of large discharge. The pump was credited with creating these two velocities.

Mr. Smetters: What length of pipe would you specify for head and discharge?

The Author: The diameter of pipe is limited by design of pump. We take into consideration the friction head and discharge through suction pipe. The length of discharge pipe is immaterial, provided we take care of the friction between pump and gauge. The idea is to have the pressure gauge as close to the pump as practicable. If you take care of the friction loss between pump and gauge the length of pipe is immaterial.

President Lee: The question of pumping is nearly as old as civilization. I have been given to understand that the preferred installation is growing to be the centrifugal pump. In fact, I have recently heard of the substitution of heavy duty centrifugal pumps for the tremendous pumps with which we are familiar in large pumping stations for service in cities. It is a very interesting subject and I would like to hear from Mr. Baker.

H. S. Baker, M. W. S. E.: I did not come to speak on centrifugal pumps, but to learn something about them. Like most water works engineers, we are interested in that subject. The City of Chicago has several centrifugal pumps in service, of which the large sewage pumps at 39th Street and Lawrence Avenue are the oldest and are driven by direct-connected steam engines.

In 1911 two water works pumps were installed at 22nd Street. They are operated by alternating current motors of 1,000 h. p., the pumps having a capacity of 25 million gallons per day against a 115 foot head, and 20 million gallons per day against a 130 foot head. Each unit was specified to give a combined efficiency of 67.5%.

Later on, two steam, turbine-driven, centrifugal pumps, built by the Allis-Chalmers Company, were installed at the Lake View pumping station. These pumps are designed for 20 million gallons capacity, are driven by 600 h. p. steam turbines and pump against a 120-foot head. They run 1,500 r. p. m. and have double runners. They have since been taken out of Lake View pumping station and have been erected at 68th Street pumping station, where they will be kept in service until the new pumping station is erected.

During the past two or three years Harrison Street, Fourteenth Street, Central Park Avenue, and Springfield Avenue pumping stations have been worked up to practically their full capacity through the entire summer, as well as during the cold weather, and when one engine had to be shut down there was a decided drop in pressure.

We contemplated putting in triple expansion pumping engines of the same type as already installed, but found we had not sufficient room. We secured four centrifugal pumps, manufactured by the Allis-Chalmers Company, and installed them in each of the existing stations as reserve units. They are of 25 million gallons capacity each, against 130-foot head, driven by 800 h. p. steam turbines. They have not yet been tested for efficiency, but are giving good service.

There is also one 3-million gallon, electric, motor-driven, centrifugal pump at the booster station at Mayfair. It is driven by a 100 h. p. motor with 220-volt alternating current. Two 5-million gallon pumps driven by 100 h. p. steam turbines are being installed at Roseland pumping station as booster pumps to supply Washington Heights high level district, with a guaranteed duty of 67 million foot pounds per 1,000 pounds of steam.

The design of centrifugal pumps is improving so rapidly lately that it has come to the point where any engineer planning the installation of new pumping machinery must consider them seriously.

The city of Cleveland has just purchased a 25 million gallon unit to work against a head of over 200 feet.

The city of Toronto has a number of such units.

The city of Philadelphia has received bids for a number of centrifugal pumps to be driven by steam turbines.

Buffalo, N. Y., has had for a long time centrifugal pumps driven by motors.

In New York City the high pressure fire service is supplied by centrifugal pumps.

From this it will be seen that centrifugal pumps are taking a large part in water works pumping at the present time.

The reserve units installed by the city of Chicago were put in on a guarantee of 87 million foot pounds duty per 1,000 pounds of steam. That was a couple of years ago. The modern type of triple expansion pumping engines attain a duty of 165 million foot pounds and upward.

The builders of centrifugal pumps driven by steam turbines are now claiming higher duties—up to about 140 million foot pounds.

When we consider that a duty of approximately 130 to 140 million foot pounds can be obtained with a unit that will cost $35,000 to $40,000, and that a unit of equal capacity of triple expansion type would cost $95,000 to $100,000, it appears to be a close race between them. The cost of repairs and labor for operation of centrifugal pumps will probably be low.

Tests should be made on centrifugal pumps driven by steam turbines and electric motors after they have been running for a year or more. Such tests have not been published to any extent, and would afford valuable information.

Mr. Bowen: I met a man a few weeks ago who has charge of seven large pumping stations, with heads ranging from 85 to 340 ft. He has no centrifugal pumps, but he made a statement to me which was indeed very interesting. From one of these stations (it is for irrigation purposes), the water is taken off at several different levels, making several different heads; and the statement he made was, that when the water was taken off the discharge line at maximum head the fuel consumption was quite a little greater than when a portion was taken off at high level and a portion at low level, and when the pumps were running at the same speed and therefore delivering the same volume of water. The head at pump, as indicated by gauges, was exactly the same in each case, which would indicate that the pumps were doing exactly the same work under the two conditions, but the fuel consumption was different. If this is true, which is hard to conceive, then perhaps the testing of pumps in manufacturers' plants, where heads are created by a valve in the discharge line, may give results which will differ when the same head is obtained in actual operating conditions.

SEWAGE DISPOSAL PLANT AT ABERDEEN, SOUTH DAKOTA

W. G. POTTER, M. W. S. E.

Presented June 15, 1914, before the Hydraulic, Sanitary and Municipal Section.

INTRODUCTION.

Aberdeen, South Dakota, is a town of about 12,000 population, and is located on flat prairie land, having very little fall in any direction. The city boundaries include about four square miles; the extreme variation in elevation does not exceed 15 ft. and that only in a very small portion of the city. No large streams flow within reach of the town for sewage outfall. The only stream at all available is a small, sluggish creek called Moccasin Creek, which flows through the eastern part of the city. Into this both the storm sewage and the sanitary sewage empty, and for the larger part of the year the only current in the stream is from this flow of sewage, increased by the waste and overflow from the artesian wells.

Aberdeen, being in the artesian belt of South Dakota, derives all of its water, both for the municipal supply and for a large number of private supplies, from artesian wells. The pressure from these wells is very high, the static pressure amounting in some instances to as much as 240 lb., while the hydrant pressure around town usually runs about 60 lb., with a night pressure sometimes up to or over 100 lb. One city well of 8 in. diameter gave at first about 2,300 gallons per minute discharge from a depth of 1,270 ft. Many of these wells of smaller size are left flowing all the time, and because the storm sewer system is as yet very limited, this overflow goes into the sanitary sewers, thus greatly increasing the volume to be pumped and purified. Aside from this, the sanitary sewers contain very little except domestic sewage and the wastes from several laundries.

OLD DISPOSAL SYSTEM.

The system in use heretofore has been as follows. All sewage has to be pumped. The pump station was located within a mile from the business district, and the sewage of the city is collected at this place in a 36 in. concrete sewer about 25 ft. deep. From this main the sewage entered three concrete wells inside the pump house, each 8 ft. in diameter, and each extending about 5 ft. below the 36 in. inlet pipe. In these wells were three centrifugal pumps, operated not continuously but with periods of rest lasting not over three hours, during which the sewage rose some 10 ft. or more in the wells and backed up in the main sewer correspondingly. The pumps were all submerged and hard to get at for repairs. They were operated by a vertical shaft and belted to a countershaft under the floor. The engine was a 55 h. p. Muenzel gas engine, deriving its power from one 60 h. p. and one 100 h. p. gas producers. With this engine, the sewage was lifted about 19 ft., run through a 16 in. force main about 1,000 ft., and then again lifted about 10 ft. into the septic tank. This tank was of concrete, partly with flat concrete roof and partly covered with a concrete block building. The windows and doors were all boarded up, and there was absolutely no ventilation, with the result that in places the concrete was entirely disintegrated by the sewage gases, leaving holes through the roof. There was no further purification, and the sewage entered the stream almost as foul as it entered the tank, this pollution continuing for a mile below the outlet of the stream, and emitting an odor that often reaches the residence district. Both the pump station and the septic tank were of poor concrete or concrete blocks, and as the former was in a dangerous condition, it was considered advisable to build an entirely new plant.

NEW DISPOSAL SYSTEM.

The new disposal system was planned to consist of a new pump house with larger pumping capacity, a force main to the new plant, a sedimentation tank, a sprinkling filter, sludge filter, and final settling tank.

The location decided upon was about two miles south of the town at the junction of Moccasin Creek with another small stream, Foote Creek, where some little additional flow would be obtained, at least in the spring and in wet seasons.

NEW PUMP HOUSE.

Because of the concrete pump wells and the main sewer being in good condition, it was decided to locate the new pump house upon the site of the old one. The problem became to remove the old building, erect the new one, put in an additional engine and producer, put in three new pumps, and change the position of the old engine and producers, and still keep the pumps going with no shutdown of over the three-hour period. The first thing done was to remove the old building and erect the new one with the walls on new foundations just outside the old ones, thus making the new building slightly larger than the old one. This new building was made of brick with concrete roof on steel girders. Then the old pumps were removed one at a time, the wells were filled with concrete to the grade of the incoming sewer, and cast-iron inlet pipes and gates were concreted into the old terra cotta inlets. Connected with these inlet pipes are the three pumps—one 8-in. and two 10-in. Lawrence centrifugal pumps—so that all will be operated in the dry, and easily accessible for repair. Each pump has a vertical shaft running to a beveled gear connection with a horizontal shaft above the floor. This horizontal shaft is built in three sections so that either pump may be operated independent of the other. By direct belts this horizontal shaft is connected to the old 55 h. p. and the new 100 h. p. engine. Both are of the Muenzel type of gas engine built by the Minneapolis Steel and Machinery Co. The horizontal shaft is also connected to a 30 h. p. motor for emergency, and this receives its power by wire from the Aberdeen Light & Power Co. In the producer room of the pump house the old producers have been changed in position and a new producer and wet scrubber added. Adjoining the producer room is a hopper-bottomed coal room, from which the coal is elevated to a point above the producers and distributed to each. Another room is equipped with a forge and small tools for repairing, cutting pipe, etc., for the city forces. A soft-water well of 2 in. size, about 1,000 ft. deep, is now being bored to furnish water to the producers, as it is found that the hard water from the deeper wells has a corrosive effect on the steel pans.

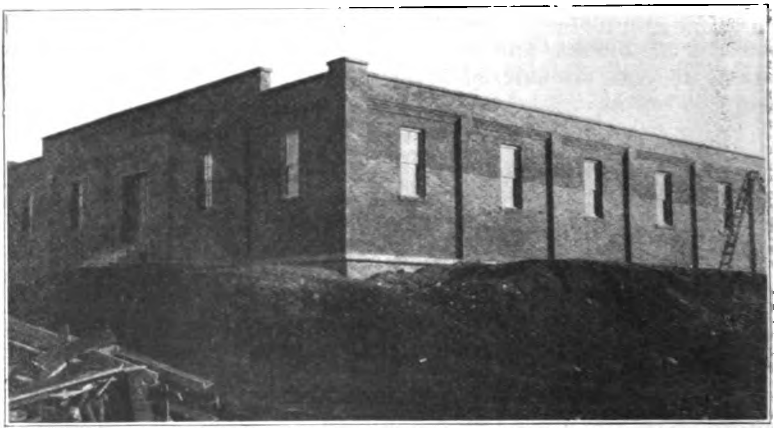


Fig. 1.—View of Exterior of Sedimentation Tank.

The reason for continuing the use of the producer gas engines was that this method has been very successful and very cheap for the old plant, and we did not wish to discard the old machinery. While I can give no accurate cost figures for the operation of the pumps, the cost has been within 1½c per kw. hour against a 6c rate from the light and power company for electricity.

The pumpage from the new station will be continuous instead of periodical.

FORCE MAIN.

From the pump station the new system will utilize about 300 ft. of the old 16 in. force main, and will then connect to the plant with a new 14 in. main about 9,400 ft. long. The pumpage through this main will be normally about 1,500,000 gallons per day, which will give a barely self-cleansing velocity. It is considered that this pipe will carry the sewage without excessive friction until the discharge is about doubled, when another parallel pipe will be necessary. The force main is laid on a gravity grade from the pump station to the plant, with a by-pass at the plant, so that in case of not being able to pump into the plant at any time they could either pump through the main to the stream or they could empty the main entirely by force of gravity.

SEDIMENTATION TANK.

The sedimentation tank is rectangular in shape, 64 ft. by 73 ft. outside, and consists of three units, any one or all of which may be used at one time. Each unit has three pockets, 20 ft. by 23 ft. at the top and 2 ft. by 5 ft. at the bottom, in the shape of an inverted square pyramid. Suspended angle walls form the upper story from which the sludge falls into the pockets. As the sewage is almost altogether domestic in quality, no grit chambers are used and the entrance of the sewage will be at one end of the tank only, through a 14 in. pipe in each unit from the force main, this pipe turning up inside the tank to a point about 6 in. below the flow line. The depth of pockets and of sewage will be 17 ft. The flow line of the tank is about 10 ft. above the natural ground line. The outside walls of the tank are 15 in. thick at the coping near the top and 24 in. at

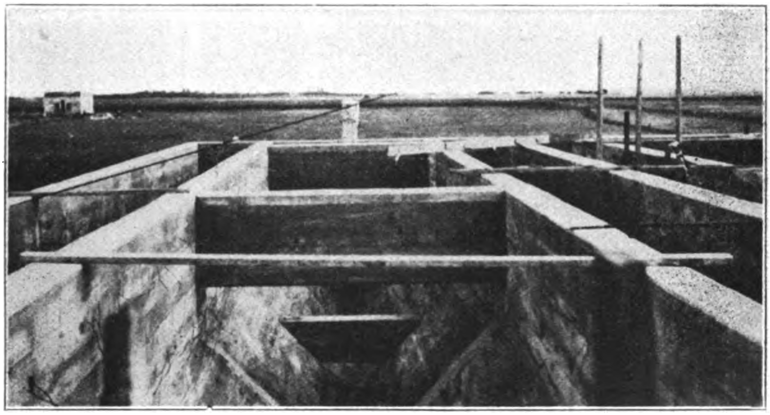


Fig. 2.—View of Interior of Sedimentation Tank Showing Inclined Sedimentation Floors.

the bottom, with piers extending well below the frost line at the corners and at the intersection of the unit walls with the pocket cross walls and outside walls. All are heavily reinforced. Above the coping of the outside walls the concrete is 3 ft. high and about 8 in. thick, with a facing of brick outside. Above the concrete is a building of brick and hard-burned tile, for the purpose of keeping the sewage warm and accessible during the winter. This building covers both the sedimentation tank and siphon tanks, and has a roof of wood construction supported by posts on the unit walls and covered with Carey roofing. Ventilation is secured by means of doors, windows, and three ventilators in the roof.

No waterproofing was necessary, except painting the inside surfaces with asphalt paint. Very few seeps were found on filling the sedimentation tank, and those were caused by water following the wires used in holding the forms together. All seeps were easily stopped by using a little pitch on the inside at these places.

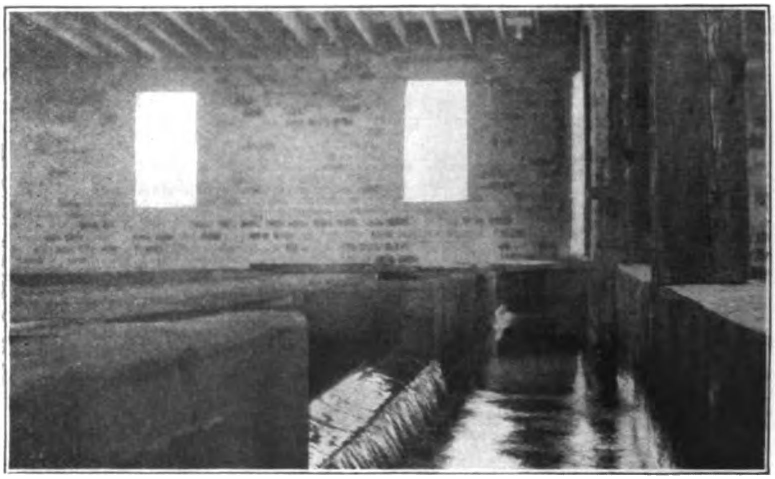


Fig. 3.—Interior of Sedimentation Tank in Operation.

Each pocket has its sludge pipe and valve, 8 in. in size. and the pipes from the corresponding pockets in the three units combine, forming three main sludge pipes which extend through the east wall of the sedimentation tank to the sludge filter.

THE SLUDGE FILTER.

The sludge filter is located 30 ft. east of and parallel to the sedimentation tank. It is 32 ft. by 67 ft. in size, uncovered, and built of plain concrete with 12 in. walls. It is laid with a 6 in. floor, in which are shaped concrete drains about 5 ft. apart.

The walls of the filter come up to about the natural ground line. and the depth is 4½ ft. at the north end and 5 ft. at the south end. The filter material consists of about 18 in. of crushed stone from 2 to 4 in. in size, above which is 12 in. of coarse gravel. The three mains from the sedimentation tank enter the filter just below the top of the wall on the west side, and each divides into a system of 4-in. cast-iron laterals supported on piers just above the surface of the gravel. Each of these laterals is slotted for nearly its full length and open at the end to facilitate cleaning. In operation, after receiving the charge from the sedimentation tank, the sludge is allowed to dry on the filter. The liquid filters down to the sub-drains, and is carried away through a 12 in. main to the filter by-pass, and runs through that around the outside of the sprinkling filter to the filter trough, thus getting the benefit of passing through the final settling tank. To facilitate removal of the dried sludge, two tracks of 24 in. gauge, for industrial cars, are laid on concrete piers over the surface of the filter. The dried sludge will be spaded by hand into the cars and then removed to low ground and used for a filler.

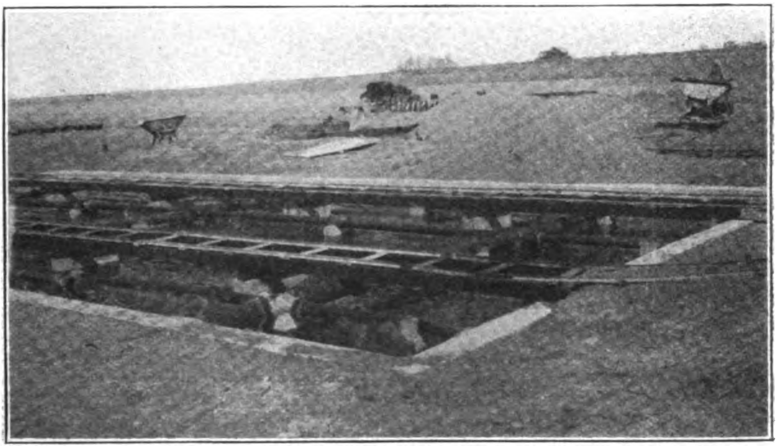


Fig. 4.—Sludge Filter In Operation.

SIPHON TANKS.

The liquid, after passing through the sedimentation tank, passes over an 8 ft. weir in each unit, and into a trough, from which it goes through two 18-in. sluice gates into the two siphon tanks. These are adjoining the sedimentation tank, and are covered by the same building. They are each 16 ft. square at the top with three sides sloping, 10 ft. square at the bottom, and are fitted with a 14 in. Miller siphon of 5 ft. maximum discharge depth. Each one of the siphon tanks contains about 7,000 gallons when at discharge depth, and when running together each will discharge about once in fifteen minutes. Veeder trip counters will be used with float attachments to register the number of discharges of each siphon.

The siphons discharge into a 14 in. main between siphon tanks and sprinkling filter, and branch 14 in. mains enter the filter in two places. By control of the gate valves, either siphon may be used for either half of the sprinkling filter, or all of it, and if necessary the discharge of the siphon may by-pass the filter altogether and come into the final settling tank.

SPRINKLING FILTER.

The sprinkling filter is 143 ft. by 209 ft. inside, with plain concrete walls 8 in. thick at the top and 16 in. at the bottom. A 6 in. concrete floor is laid throughout, and in it, about 4 ft. apart, are 8 in. terra cotta half tile sub-drains. Each sub-drain has a flat concrete cover, 18 in. long, 10 in. wide, and 1½ in. thick, with two ribs which raise it 1½ in. above the floor to allow the water to enter. These covers were designed and cast in Aberdeen and well seasoned before using. The filter floor has a fall to the south of 1 ft. in the width of 143 ft. On this floor crushed granite of 2 in. to 4 in. size was spread to a depth of 5½ ft. at the north end and 6½ ft. at the south side. One hundred and seventy-two carloads of rock were necessary to fill the filter to the required depth.

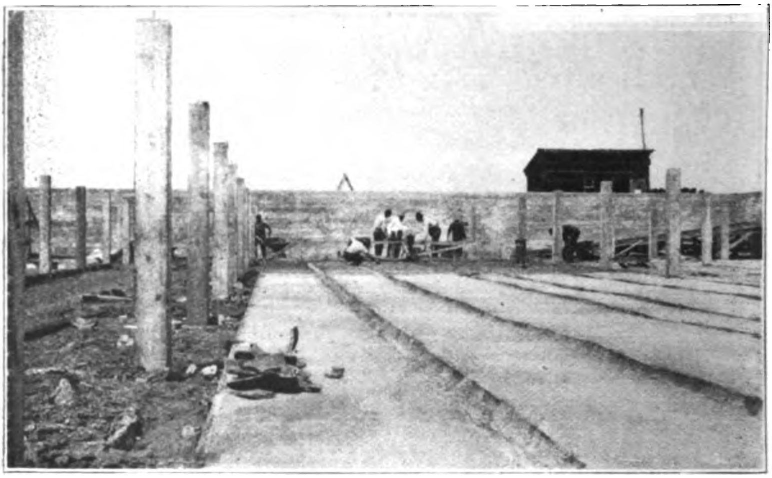


Fig. 5.—View of Sprinkling Filter Showing Drainage Channels and Roof Supports.

The 14 in. main distributer enters the filter from the siphon tank in two places, each controlled by its gate valve. These mains run south through the filter on concrete piers about 1 ft. above the floor. Every 13 ft. on each main a 6 in. lateral extends east and west, and at each 13 ft. on each lateral is a 3 in. riser pipe, on which is a Taylor square nozzle. There are 88 of these nozzles on each main, or 176 altogether in the filter.

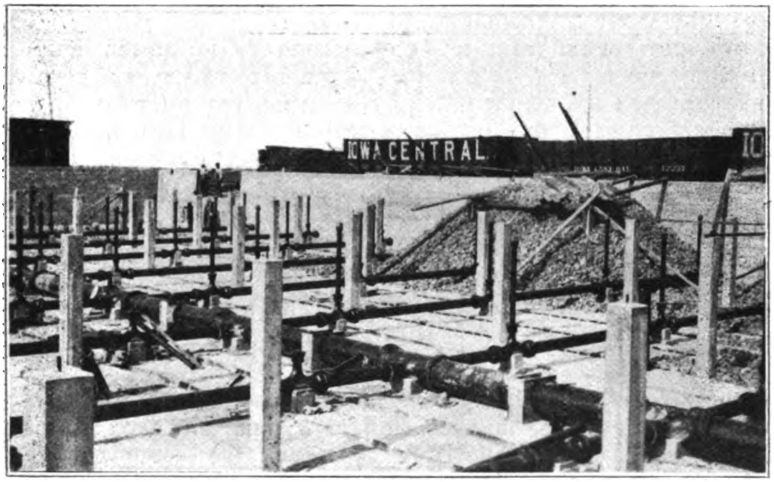


Fig. 6. Sprinkling Filter Showing Piping Arrangement for Sprinkler Heads.

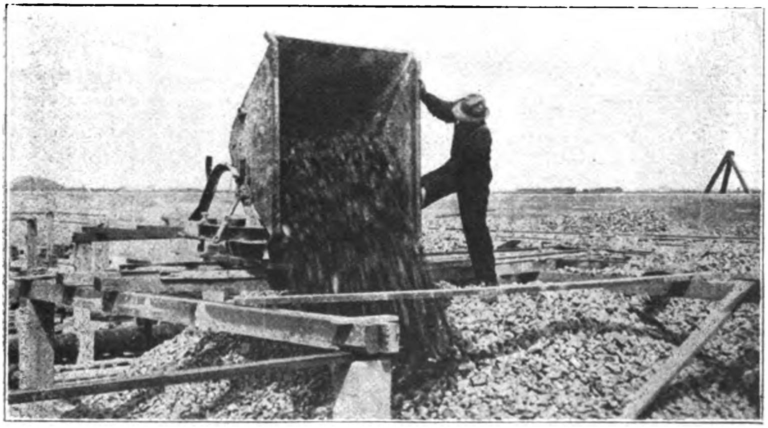


Fig. 7.—Sprinkling Filter Being Filled with Broken Stone.

Each lateral is laid on a grade to drain to its main, and each main drains to the south end. There each main has a 2 in.

drain running to the filter trough, which may be opened by a stopcock, thus draining the entire distribution system if necessary at any time.

On account of the usual extreme cold during the winter season, some precautions were necessary to prevent freezing of the nozzles and filter. For this purpose, concrete piers were built midway of the nozzles, and 13 ft. apart in each direction. On these piers, rising above the surface of the stone about 6 in., 4 by 4 posts were erected with 4 by 6 stringers, and on this framework a temporary winter cover of 2 in. plank is laid. The plank cover only will be removed during the warm season, the framework being left in place, although this framework is so built as to be removable without drawing a nail. This roof is of a flat hip roof construction with 3 ft. rise to the center. All

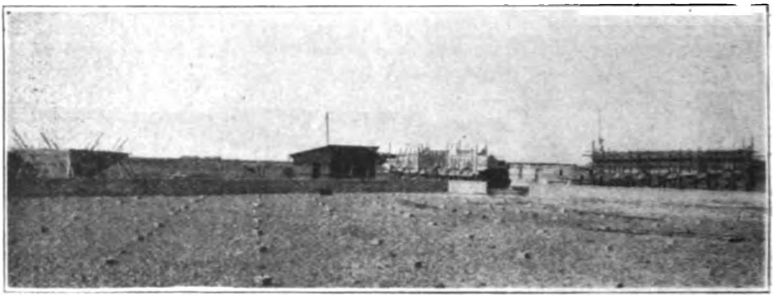


Fig. 8.—Sprinkling Filter Completely Filled with Filtering Material.

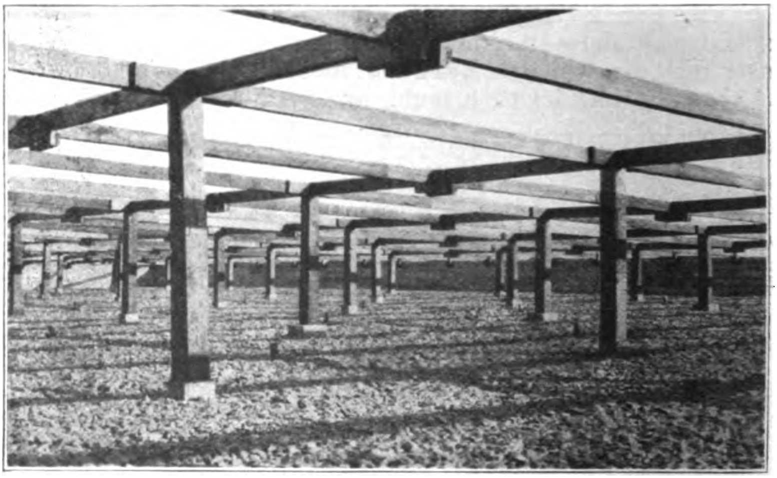


Fig. 9.—Sprinkling Filter Showing Roof Structure.

wood used on this was painted with a wood preservative before using.

The sprinkling filter covers 0.68 of an acre, and with the present normal flow of about 1,500,000 gallons per day it will have a loading of about 2,200,000 gallons per day per acre.

COLLECTING TROUGH.

Running along the south side of the sprinkling filter, and separated from it by the filter wall only, is the collecting trough. It is 3 ft. wide, with a floor slightly below the filter floor; the outer wall is about 4 ft. lower than the filter wall and comes up only to the ground line. Arches are built in about 25 ft. apart over the trough to counteract earth pressure from the outside.

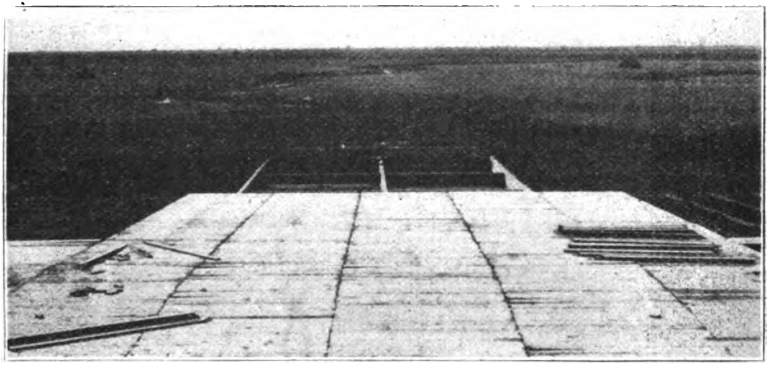


Fig. 10.—Sprinkling Filter Partly Roofed Over.

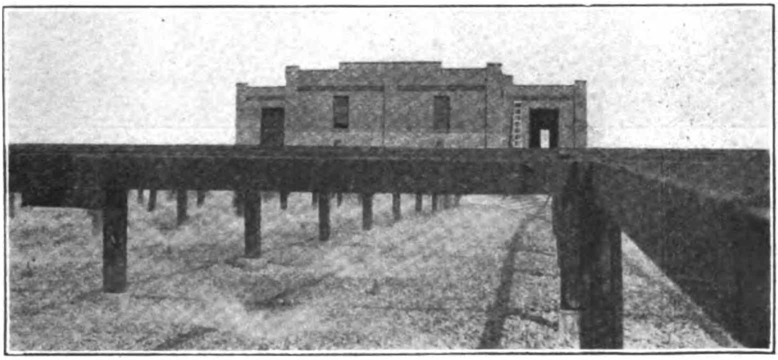


Fig. 11.—Sprinkling Filter In Operation—Sedimentation Tank in Background.

All of the filter sub-drains pass through the filter wall and empty into this trough. At the east end of this trough also the filter by-pass mentioned above enters, carrying the water from the sludge filter and from the siphon tanks in case the filter should for any reason be put out of service. Likewise, the force main by-pass has a connection by which the entire plant above this point could be put out of service, if necessary, and still give the sewage the benefit of the final settling tank. This trough could also, in case of a typhoid epidemic or similar trouble, be used for a hypochlorite trough. After the liquid passes into this trough, it flows from either way to the centre and then through a covered trough to the final settling tank.

FINAL SETTLING TANK.

This is a plain concrete tank 63 by 103 ft. in size, divided into two parts by a middle longitudinal wall. From the collecting trough the flow enters a shallow, reinforced hanging trough, the flow into either half being controlled by a gate. From this trough it passes over a weir the entire width of the tank, to the tank proper. Here it passes slowly through under several reinforced baffle walls to the outlet end. The tank is about 4 ft. deep below the flow line, and it takes the normal flow about two hours to pass through, thus allowing the suspended solids a final chance to settle to the bottom. The floor of the final tank is below the outfall creek, and when either compartment is emptied for cleaning, it will have to be done by gasoline pumps. From the final tank the effluent passes over two weirs in each half into a final trough, and from there through

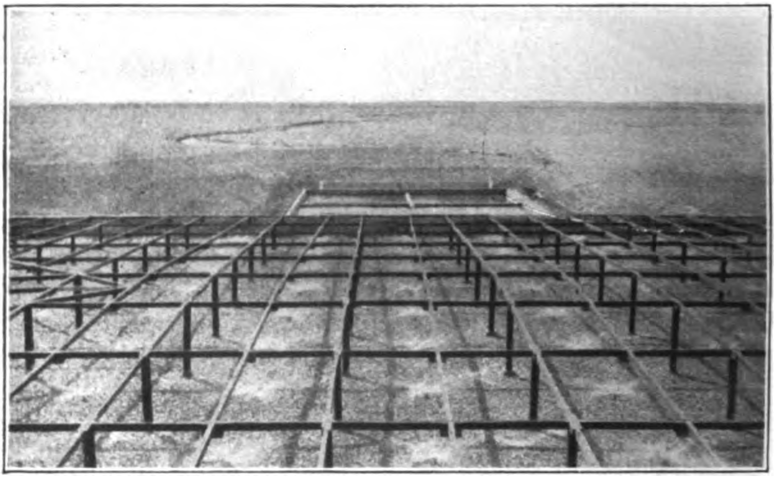


Fig. 12.—Sprinkling Filter in Operation—Final Settling Tank and Outlet Stream In Background.

about 200 ft. of 20 in. terra cotta pipe to the final outfall into the stream.

HEAD CONSUMED THROUGH PLANT

The elevation of the main sewer at the pump station is about 74. The sewage is pumped up to elevation 100 at the flow line of the sedimentation tank. The discharge of the siphon tanks is at about 99.5 and the elevation of the sprinkler sprays is 91.5. The floor of the sprinkling filter is 84.5 at the south end, the flow line of the final settling tank is 84.0, and the grade of the pipe at the final outlet is 83.2. This makes a total head consumed in the disposal plant of 16.8 ft.

AUXILIARY WORK.

Part of the auxiliary work connected with the proposition was the construction of two small reinforced dams across the two streams for the purpose of preventing the backing up of the effluent towards town in case of a south wind and no current. A 2-in. artesian well was also bored about 1,000 ft. deep to furnish water for construction and for other uses. A living house was moved from the site of Aberdeen's new City Hall, about three miles to the disposal plant, set up on a concrete foundation and remodeled. It was connected with the well and given sewer connection, and is being used by the caretaker as a residence.

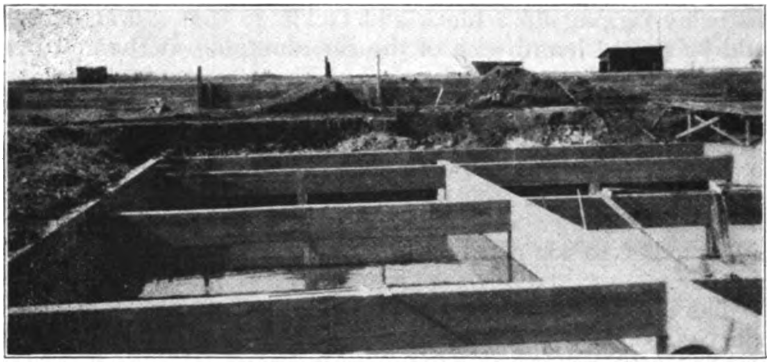


Fig. 13.—General View of Final Settling Tank.

About 1,800 ft. of railroad track was put in by the M. & St. L. Railroad to facilitate unloading material.

GENERAL REMARKS AND COST.

All concrete was composed of Northwestern States Portland cement and pit-run Kampeska gravel, in proportions varying from 1 to 4½ to 1 to 6. This gravel was taken from below the water of Lake Kampeska, about 100 miles from Aberdeen, and is remarkably free from dirt or other foreign material. It made a very dense and solid concrete.

In construction a 35 ft. tower was erected between the main sedimentation tank and the sludge filter, and all concrete for these and for the siphon tanks was spouted from the tower to position. Gravel and cement were brought to the mixer by Koppel cars. The concrete was raised in the tower, and the gravel was drawn up an incline to a pocket above the mixer by the use of one team.

For the sprinkling filter and the final tank, the mixer was erected along the railroad spur, and all gravel was shoveled direct from the railroad car to the mixer. The concrete was run from the mixer into Koppel cars on 24 in. gauge tracks, and pushed by hand to the place of dumping. The crushed stone for the filters, of which 175 carloads were used, was unloaded mostly by rigging up a block and tackle so that a drag-scraper could be pulled lengthwise of the car, dumping at the end over a trap into a Koppel car beneath. This arrangement cut the cost of unloading and moving the stone into position by about 50%from unloading by hand.

Labor was paid 22½c per hour at first, followed for the most of the work by 25c per hour, and was very hard to get during the summer and fall seasons. Form carpenters were paid from 35c to 45c per hour and brick masons from 70c to 80c per hour.

The total cost of the plant will be about $130,000, of which about $20,000 will be for reconstruction of the pump house and its new machinery, $9,000 for land and right-of-way costs, about $20,000 for the force main, $17,000 for crushed stone, and the balance for concrete materials, labor, etc. The bond issue for this work was $200,000, so that there is an unexpended balance of $70,000.

Sewage was started through the new plant about April 1st, but it will still be some time before the changes in the pump station are complete.

The entire work, excepting part of the excavation, part of the pipe hauling, and the construction of the pump house building above the foundation, was done for the Commissioners of the city of Aberdeen by city forces without contract, the writer being the designing and constructing engineer, and W. D. Northen, of Chicago, the general foreman. Most of the changes of machinery in the pump station were made by Mr. W. F. Hoberton, Supt. of Water and Sewer. It is a good example of non-political municipal work, and the writer is very glad to say that politics was one of the incidental troubles that was entirely absent from this work.

DISCUSSION.

W. D. Gerber, M. W. S. E. (Chairman): One of the principal points of interest in connection with this plant at Aberdeen is, I believe, the fact that it was designed by a special engineer (the author of the paper presented this evening) employed for that purpose, and constructed on a force account basis by the City. This is rather a departure from the general practice.

The Author: Changes in the pumping station are still being made, and because of the operation of the pumps the work is proceeding very slowly. It will probably be another month before the changes are completed.

The cost of concrete work ran from $3.25 for the concrete floor in the sprinkling filter up to about $8.25 on part of the reinforced work.

The cost of unloading stone in the sprinkling filter at first ran from 45c to 60c per yard. Later we were able to cut it down to 19c to 24c per yard by working the drag scraper lengthwise of the car and dumping through a trap into Koppel cars. Most of the cars used were gondolas. The average final cost was about 32.4c for unloading stone from the cars and putting it in place in the filter.

Mr. Gerber: The construction of such a plant is an interesting problem, and one that usually requires special consideration. I think perhaps Mr. Sherman can give us some points on constructing concrete work of this character.

L. K. Sherman, M. W. S. E.: The plant at Aberdeen furnishes two interesting features. One of them is the location of a sprinkling plant so far north, where provision had to be made for an extremely low temperature. We shall be interested to learn the future results.

The other interesting feature is that today the people themselves are taking a higher view of necessities and requirements. We have been accustomed to thinking that sewage disposal plants were forced upon us by community growth; in other words, where the population became dense, we took care of the situation by building a plant to prevent being a nuisance to our neighbors. That we have advanced and will not put up with what we did twenty years ago in the line of sanitation is exemplified, I think, in this plant at Aberdeen.

We have also become more rational in our views regarding sewage disposal. Some time ago, in speaking of sewage disposal, we said "sewage purification." Nowadays, all prominent men in sanitation work speak of it as sewage treatment. They have helped the cause of sewage disposal in not leading the layman to expect from sewage plants that which he cannot get.

The efficiency of the work done at Aberdeen is worthy of especial note. I am not prepared to say whether contractors would have built the plant cheaper than Mr. Potter did, but it looks as though the work was done very reasonably. The use of the siding for unloading cars was ingenious and I have not seen this done elsewhere. The concrete tower is, of course, standard practice.

In Mr. Potter's design, the sludge pipes do not extend from the valve to the surface, as is the general practice. As I understand it, the reason sludge pipes are generally run close to the top with an opening is so that a stick may be poked down, expecting that the pipe may clog. I have never heard of the use of a stick being necessary, and I do not know that the pipes do clog, but this is the first plant I have noticed in which that feature has been omitted.

Mr. Gerber: The point Mr. Sherman brought up in regard to the design of sludge pipes is a good one. The feature doesn't cost much, and in this respect it is like a good many other precautions. A man, for instance, will carry accident insurance, and yet may never have an accident. The device may never be used, but if we want it, we want it badly.

The Author: Mr. Sherman called attention to the sprinkling filter being used so far north. There are a number of sprinkling filter plants used in Saskatchewan and Alberta, but they are inclosed in buildings. In the case of the plant at Aberdeen, we have merely a temporary winter cover, which is taken off in the warmer season. They have several sprinkling filter plants of the English type, and disposal plants, in Canada, some of which have been running for the past two years, which I think have done very well. I am expecting to get considerable information from Aberdeen this coming winter in regard to that plant, and also in regard to plants in the extreme North.

Langdon Pearse, M. W. S. E.: The author shows that the expenditure was about $130,000 for 12,000 people. Were 12,000 people actually connected to sewers? Also, it would be interesting if the author would give us the itemized cost, distinguishing the cost of settling basins, sprinkling filters, secondary tanks, and sludge tanks. showing the distribution of costs as compared with other plants. What I would like to know particularly, is whether, for instance, the settling plant cost $35,000, the sedimentation tank $10,000, and the sludge tank $2,000. Something in that general way would be very instructive. I have sought data available on such works in connection with our investigations for the Sanitary District and have found considerable variation of cost throughout the country. For instance. costs based on census figures do not agree with the figures covering material actually handled, per capita; the figures will run three times as high for some places as for others.

I would also ask the author whether he had any difficulty in forming the sloping walls and baffles of the settling chamber in the sedimentation tank.

The Author: The sprinkling filter cost $35.000, including the rock in place. The rock amounted to 5,500 cu. yd. The rock-cost was $2.96 per cu. yd. f. o. b. cars. The cost of unloading including placing was about 32c. The sedimentation tank cost $13,000. These figures are approximate only. The siphon tank cost $1,500. The sludge tank cost about $2,000. The final tank cost about $4,000. In connection with the building of the final tank we had considerable water to contend with. The pumping station, including new machinery and changing the position of the old machinery, cost $25,000. The land-cost amounted to $9,000 for 80 acres, of which about three acres are in use.

There was considerable general work. For instance, we had a good deal of dirt to excavate. Then there were the two dams, the by-passes, the attendant's house, and such things, that could not be included in the cost of any one of these different parts, but still were included in the total cost. The inclined walls were about 8 in. thick, built of plain concrete. They were built by making a form for the pocket; on account of its weight, we cut the form in two, horizontally, and handled each half by means of a derrick; we put the entire form in place for each pocket, concreted the pocket, pulled the form out, and used it for the next. We had no trouble whatever in building the walls.

Mr. Sherman: I recently constructed some of these baffle walls where the situation was very much cramped, and the forms could not be taken out after they were once in place. We built them in sectional slabs, on the ground, with expanded metal. We poured mortar on the slabs and let them lie on the ground, with a part of the expanded metal protruding at the ends. When the slabs were assembled, mortar was poured over the metal which protruded, and the whole became bonded together. The method proved a successful one, and much more economical than building the walls in place and setting forms on both sides.

The Author: Form work is expensive, on sedimentation tanks especially, not only as regards cost of material, but for labor.

Mr. Gerber: There are two points brought out in this discussion on which I might give our experience. The first one is that of extending the sludge pipe above the water line.

About the year 1901 we built a plain septic tank of the old flat bottom type. The man in charge was very conscientious and I was able to get from him a great many points in regard to his experience in the handling of the sludge. According to this gentleman, sludge which was allowed to stand for a period of six months or more was extremely difficult to pump on account of the compactness of the deposit. It was also his experience that it was necessary to periodically remove the scum or mat which formed on the surface of the so-called digestion chambers, for the reason that if this mat was allowed to stand and become ripe and settle to the bottom of the tank, it formed a sort of gummy mass that became almost impossible to handle even with an 8 in. centrifugal pump. He stated to me that he was able to tell purely from observation when the mat was about ripe and it was his practice to skim it off at these times. When the scum was thus prevented from settling to the bottom of the tank, it was found that the sludge proper could be very readily handled by the pump and that it did not set up so densely as when the scum was not removed.

In another plant which has only been in service two years it was possible to provide sludge pipes with the discharge 5 ft. below the water line in the tank; the vertical portion of the sludge pipe was not carried above the water line. After the tank had been in service about a year an attempt was made to clean out the sludge pockets, and we found that the sludge had settled in so tightly that it did not move under the action of the 5 ft. head. It was necessary to install a pump and draw down the liquid in the tank to below the level of the discharge line of the sludge pipe. The elbow was tapped out to provide for the insertion of a 1 in. pipe nozzle. By putting water pressure on this nozzle we were able to jet the compacted sludge away from the bell mouth of the sludge pipe and get the action we desired. Since this experience, our practice has been to carry the sludge pipes above the flow line.

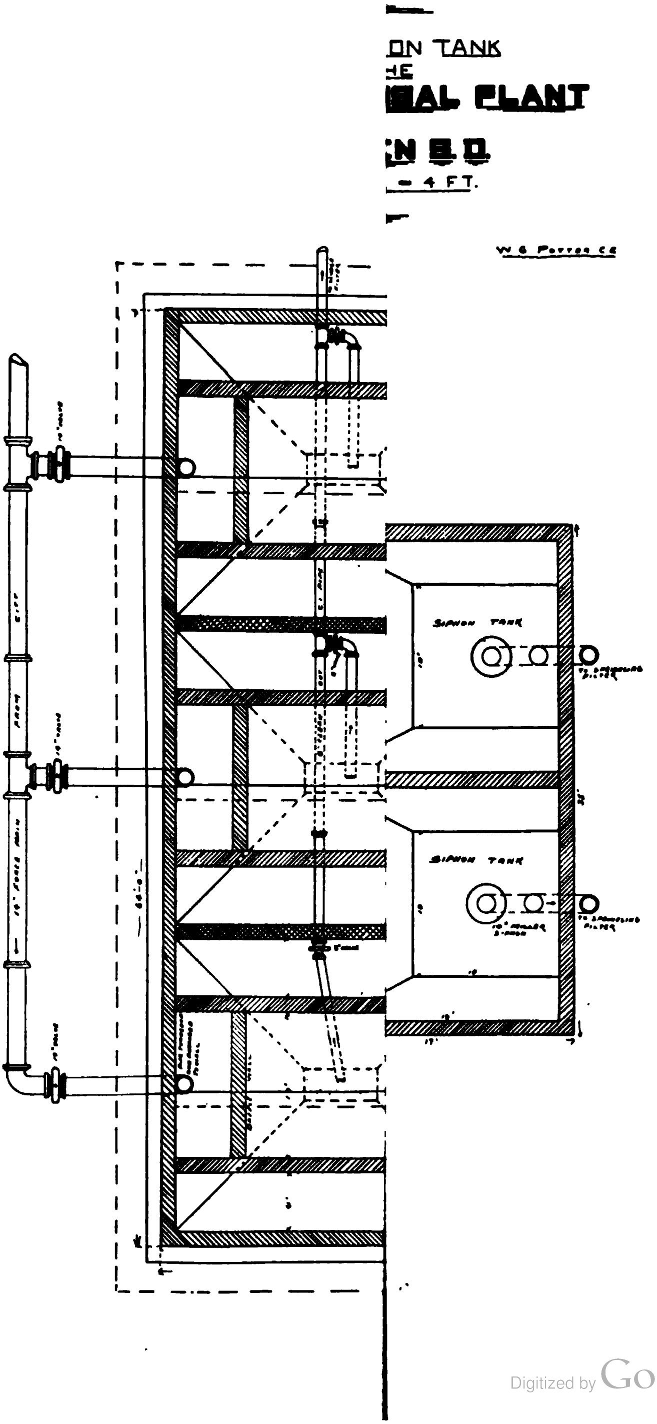
The question of removing the forms for the casting of inclined walls in the tank proved a rather serious problem in one of our recent designs, and to obviate this difficulty we provided reinforced rectangular beams on which were placed reinforced concrete slabs 2 in. thick. These slabs could be placed from above and when so placed were grouted in with cement mortar. About the only difference between our construction and that referred to by Mr. Sherman is that each was separate and the reinforcing was not allowed to extend beyond each individual slab.

W. W. DeBerard, M. W. S. E.: It may be of interest to know that in California they have recently changed two septic tanks at Orange into shallow Imhoff tanks. This was done with the idea that it would be an experiment, so redwood was used for the baffles and flowing-through troughs. If successful, they were to be reconstructed in a more substantial manner. The tanks were 70 ft. long, 10 ft. wide, and 7 ft. sewage depth, and were entirely covered over with a concrete roof. There was no means of getting into these tanks, and five holes had to be cut through the top of each tank. So as to make the hanging baffle walls remove the sludge and to keep the sludge from running lengthwise, tight cross partitions were constructed every 14 ft. On the bottom of the floor was laid a sort of underdrain system of vitrified pipe with thirty holes. It drained into a single pipe line and each compartment was controlled by a valve.

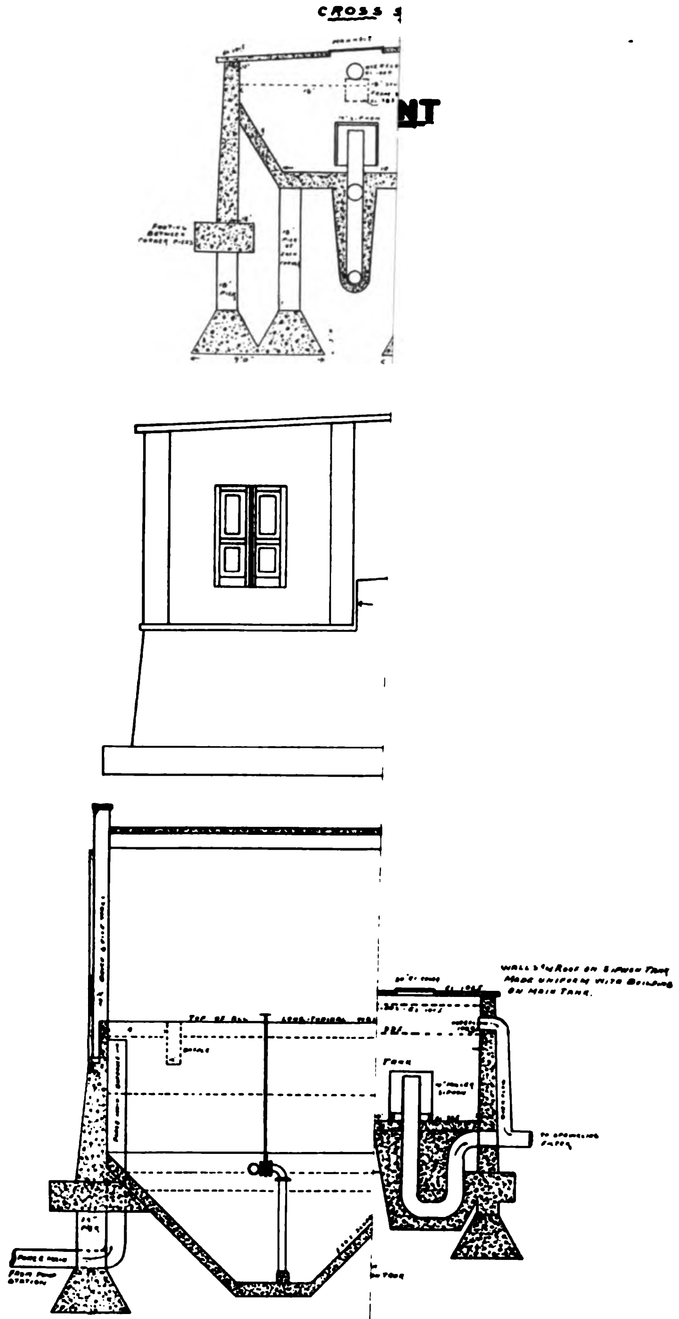
Prof. Charles Gilman Hyde, consulting engineer on this work, wrote me in August stating that he found the plant at that time working fairly well after eight or nine months' service. There was some odor of hydrogen sulphide which he attributed to the fact that

WESTERN SOCIETY OF ENGINEERS.
Vol. XIX. No. 8, October, 1914.
Potter—Sewage Disposal Plant at Aberdeen, South Dakota.

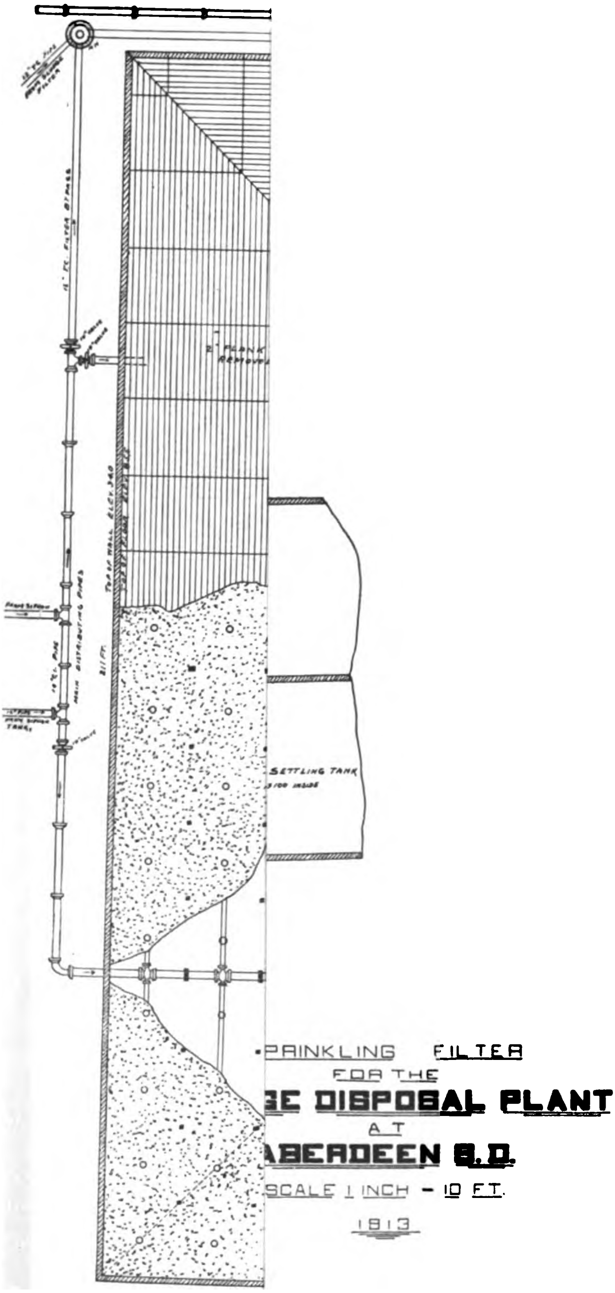
Plate I.



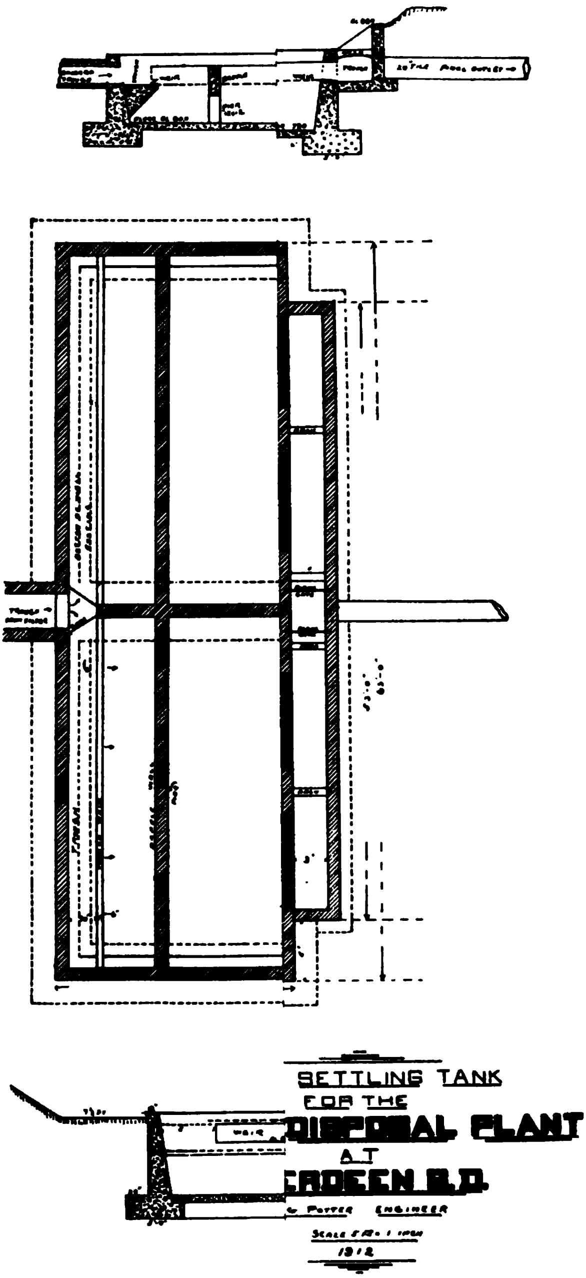
Western Society of Engineers.
Vol. XIX. No. 8, October, 1914.
Potter—Sewage Disposal Plant at Aberdeen, South Dakota.
Plate III.


CROSS S
NT
TOP OF
FROM PUMP STATION
TANK
WALLS & ROOF ON SIPHON TANK MADE UNIFORM WITH BUILDING ON MAIN TANK.
TO SPRINKLING FILTER

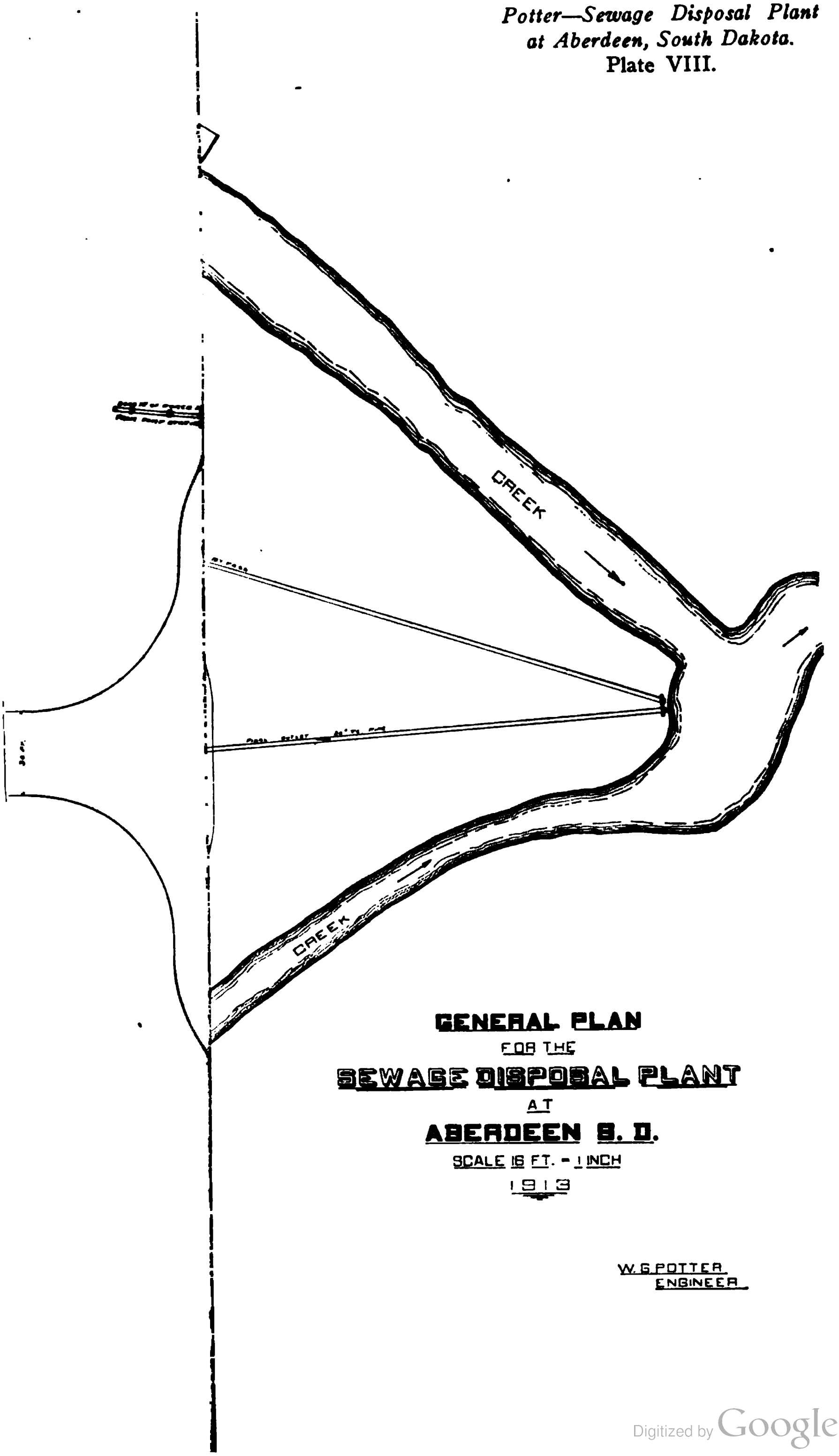
Western Society of Engineers.
Vol. XIX. No. 8, October, 1914.
Potter—Sewage Disposal Plant
at Aberdeen, South Dakota.
Plate IV.



Western Society of Engineers.
Vol. XIX. No. 8, October, 1914.
Potter—Sewage Disposal Plant
at Aberdeen, South Dakota.
Plate VI.



Western Society of Engineers.
Vol. XIX. No. 8, October, 1914.
Potter—Sewage Disposal Plant at Aberdeen, South Dakota.
Plate VIII.



GENERAL PLAN
FOR THE
SEWAGE DISPOSAL PLANT
AT
ABERDEEN S. D.
SCALE 16 FT. = 1 INCH
1913

W. G. POTTER
ENGINEER

the basins had not been cleaned of scum as often as desirable. The city water contains such a high percentage of sulphates, elimination of the gas is practically impossible if any septic action takes place. The sludge is raised from the sludge pit by means of a centrifugal pump. Notwithstanding the action of the pump upon the sludge, which would tend to liberate the gas therefrom, it seemed to dry readily and to be fairly porous and typical of sludges from deeper Imhoff tanks.

The Author: It is a question whether the condition of the tank at Aberdeen was not in a measure due to the class of material used in the concrete. The local sand used in this work has a great deal of shale in it. I think that, possibly, was the cause of disintegration.

Mr. DeBerard: The reason for changing the type of tank in the California plant was not because it was not used for city sewage, but because it *was* used for city sewage, and made more or less of an odor. The water supply of the town was full of sulphates, equivalent to from 150 to 500 pounds per million gallons.

A. T. Maltby, M. W. S. E.: While listening to the reading of this paper there were two things that impressed me. One was that the power provided at the pumping station consists of one 55 h. p. and one 110 h. p. engine, or a total of 165 h. p. The plant, as I understand it, was designed to handle 1½ million gallons per day and the difference in elevation is 26 ft. As the theoretical requirements are only about 6½ h. p. for 26 ft. elevation it would seem that you are providing for a considerable excess of power.

My next point is in regard to the depth of the tank; I infer from the reading that it is 17 ft. The general practice in this type of tank seems to be about 30 ft. It is claimed that with this greater depth a better grade of sludge is produced. In other words, a sludge that is better digested and that will dry out to better advantage. There has been considerable discussion on this subject and it would be of interest if the author would keep in touch with the operation and results obtained from this tank. If the shallow type of tank will produce an acceptable character of sludge, it will be a good thing to know, as it would cheapen the cost materially.

The Author: In regard to the power. We have a 26 ft. lift besides the friction from the two mile force main. And then, too, the larger size engine was put in with a view to some day using that power also for another purpose for the city—running some of the boulevard lights.

I think the depth of tanks in Germany is 30 to 40 ft., but there are a number of plants in this country in which the tanks are not so deep. It will be interesting to watch the Aberdeen plant for the coming year or two years, to see what is the effect.

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS

Regular Meeting, September 14, 1914

A regular meeting (No. 872) was held Monday evening, September 14, 1914, which was also a meeting of the Bridge and Structural Section. The meeting was called to order at 7:45 p. m. by President Lee, with about 130 members and guests present.

The Secretary reported from the Board of Directon that at their meeting held July 2 the following had been elected into the Society:

Horace C. Alexander, Chicago	Member
Robert H. Schwandt, Chicago	Affiliated Member
Burke Smith, Chicago	Member
Murray Blanchard, Chicago	Member

And that the following had applied for admission:

No. 44, Ernest R. Houskeeper, Chicago.
No. 45, Earl K. Burton, San Juan, Porto Rico, transfer.
No. 46, Manuel M. Llera, New York City.
No. 47, Harold F. Beyer, Crystal Falls, Mich.

Also that at the Board meeting of August 3d the following were elected into the Society:

Ernest R. Houskeeper, Chicago	Associate Member
Earl K. Burton, San Juan, Porto Rico, transferred to	Associate Member
Manuel M. Llera, New York, N. Y	Member
Harold F. Beyer, Crystal Falls, Mich	Junior Member

And that applications for admission had been received from:

No. 48, Frank Xavier Loeffler, Chicago, transfer.
No. 49, Earl W. Evans, New Orleans, La., transfer.

Also that at the Board meeting held September 2 the following had applied for membership in the Society.

No. 50, Aaron J. Winetz, Chicago.
No. 51, Harry M. Engh, Milwaukee, Wis.

And that two members, as follows, had been transferred:

No. 48, Frank Xavier Loeffler, Chicago, from Student Member to Junior Member.

No. 49, Earl Webster Evans, New Orleans, from Junior Member to Member.

Also that one excursion was had, July 25, to Clearing, which was reported in detail in the September Journal.

After the Secretary had made his report President Lee introduced Prof. Morton O. Withey, of Madison, Wis., who presented, in abstract, his paper on "Permeability Tests on Gravel Concrete." Discussion followed from President Lee, W. H. Finley, J. H. Libberton, T. L. Condron, E. B. Wilson and F. E. Davidson, with replies and explanations from Professor Withey.

President Lee then introduced Mr. N. M. Stineman, ASSOC. W. S. E., who presented his paper on "Reactions in a Three-Legged Stiff Frame With Hinged Column Bases." This paper had been printed and sent out in advance and was presented in abstract only. The Secretary read a letter from Prof. J. J. Richey of the Texas Agricultural and Mechanical College, offering some remarks on Mr. Stineman's paper.

Meeting adjourned at 9:50 p. m., when refreshments were served.

Regular Meeting, October 5, 1914

A regular meeting (No. 873) was held Monday evening, October 5, 1914.

The meeting was called to order at 8:05 p. m. by the Second Vice-President, Ernest McCullough, and with an attendance of about ninety members and guests.

The reading of the minutes of the preceding regular meeting, September 14, was dispensed with by consent.

The Secretary reported from the Board of Direction that applications for admission into the Society had been received from:

No. 52, Thomas Grover Dunn, Gorham, Ill.
No. 53, Arthur A. Heeren, Chicago.
No. 54, Albert Austin Chenoweth, West Lafayette, Ind.

Also that the following had been elected into the Society:

No. 50, Aaron J. Winetz, Chicago, Member.
No. 51, Harry M. Engh, Milwaukee, Wis., Associate Member.

The Secretary also stated that the Society is invited to attend the meetings of the state convention of Licensed Architects at Hotel La Salle, October 7 and 8, 1914.

The chairman then introduced Mr. H. E. Goldberg, M. W. S. E., who read his paper on "Arithmetical Machines," with lantern slide illustrations. There was on exhibition fourteen arithmetical machines of different makes, which were demonstrated and explained to those interested. Remarks were offered by the chairman, J. F. Hayford, J. W. McCaslin and H. F. De Revere, with replies and explanations from Mr. Goldberg.

Meeting adjourned at 9:50, when refreshments were served.

Extra Meeting, October 12, 1914

An extra meeting of the society (No. 874) was held Monday evening, October 12, 1914. This was a "Ladies' Night" and the meeting was called to order by President Lee about 8 p. m., with about 150 members and guests, including many ladies, in attendance.

The President offered a few remarks of welcome and introduced Mr. W. R. Patterson, M. W. S. E., who gave an interesting account of a recent trip through the Yosemite and Yellowstone National parks, illustrated with many beautiful lantern slide views. These pictures also included some views of the Panama-Pacific International Exposition under construction and along the Chicago, Milwaukee & St. Paul Railway on the way to Gardner, the entrance of Yellowstone Park.

Some piano and vocal music was given preceding and following the address. The meeting adjourned about 9:30, when refreshments (ice cream and cake) were served.

Extra Meeting, October 19, 1914

An extra meeting (No. 875) in the interests of the Hydraulic, Sanitary and Municipal Section was held Monday evening, October 19, 1914.

The meeting was called to order at 7:50 p. m., Mr. W. D. Gerber, chairman of the Section, presiding, with about fifty-five members and guests in attendance. There was no business before the meeting, so the chairman introduced Mr. Robert M. Feustel, of the Public Utilities Commission of Illinois, who read his paper on the work of the Illinois Utilities Commission. Discussion followed from Messrs. W. D. Pence, Douglas Graham, W. H. Finley and P. Junkersfeld, with replies and explanations from Mr. Feustel.

Meeting adjourned at 8:50 p. m.

J. H. WARDER,
Secretary.

October, 1914

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THIS SOCIETY

TECHNICAL MECHANICS. Third Edition. Rewritten by Edward R. Maurer, Professor of Mechanics in the University of Wisconsin. Cloth, 6 by 9 in., 356 pages, 547 figures. New York, John Wiley & Sons. $2.50 net.

This is a complete revision of a well-known and widely used textbook. It is divided into two parts: Statics and Dynamics. Under Statics the chapters on Composition and Resolution of Forces, Forces in Equilibrium and Simple Structures are not as clear as in the previous edition; some additions have been made to the chapter on Friction; the chapter on Center of Gravity is very good, and the chapter on Suspended Cables has been extended and improved. Under Dynamics, kinetics is introduced in the chapters on Rectilinear Motion and Curvilinear Motion. The author has abandoned the "gee-pound" as a unit of mass and in its place has adopted the "slug." The chapters on Translation and Rotation; Work, Energy and Power; Momentum and Impulse; and Two Dimensional Motion are improved in the revision. Much new matter has been added, including a treatment of the gyroscope, and a chapter on Three Dimensional Motion.

At the end of the book is placed a good collection of problems, although some of them are too involved to be satisfactory for student use. Many of the problems are taken from practice and should stimulate interest.

In the opinion of the reviewer the book could be greatly improved by the use of bold face type for the important formulas (as was done in the old edition) and by distinguishing the many illustrative problems from the rest of the text by means of different type. It is also very doubtful if problems placed at the end of a book are as effective as they would be if placed at the end of the chapters to which they relate.

The older edition was sometimes criticised as overemphasizing statics. The revision and additions to the part treating dynamics have entirely overcome this criticism. Considered as a whole, the revised edition is one of the best textbooks on engineering mechanics. M. L. E.

WEATHER AND CLIMATE OF CHICAGO. By Henry J. Cox, Professor of Meteorology, U. S. Weather Bureau, and John H. Armington, Local Forecaster, U. S. Weather Bureau. Bulletin No. 4 of the Geographic Society of Chicago, by the University of Chicago Press, Chicago, July, 1914. 375 pages, 6½ by 9½ in. Cloth bound. Many illustrations, diagrams and tables. Price $3.00, postage extra.

This notable book should be of peculiar interest to engineers generally, but particularly those engaged in this territory who are concerned in structural work or in hydraulic, sanitary or electrical engineering. A study of the tables and records which show what the climate, using the word in a broad sense, has been in the past, would assist an engineer to make a forecast as to approaching climatic conditions and which would have an effect on out-of-doors operations. These tables and illustrations necessitated a considerable amount of work on the part of the authors, extending over a period of nearly five years. Chicago is situated in the middle latitudes, 41° 35′ north, nearly half way between the equator and the north pole, and here the influence of storm movements is much more marked than at other latitudes. The result is an endless and constant change in winds, clouds, rain or snow, heat or cold, thus causing great variety in our weather conditions. These are further modified by the proximity of Lake Michigan, which has a tempering effect on either extremes of heat or cold. "In this volume the features of climate and weather are treated together, the term weather including passing conditions from hour to hour and from day to day, and the term climate signifying the sum total, as it were, of weather for many years."

The book opens with an introduction covering the preparation of this bulletin, determination of climate, the location and environment of our city and the treatment of the subject. Part I covers Temperature in detail, seasonal, abnormal, etc., with details of maximum and minimum, lists of warm and cold days, occurrence of frost and illustrations of secondary controls of temperature, with many other interesting facts.

Part II considers Precipitation, whether rain or snow, periods of observation, annual, seasonal and monthly precipitation, and with comparisons at other localities, frequencies of rain and excessive precipitation, thunderstorms, hail and snow, with details, etc.

Part III takes up atmospheric moisture, relative humidity, annual and monthly, also hourly; comparison of relative humidity at Chicago and other points of this country and also the dew point, annual and monthly.

Part IV takes up the subjects of Cloudiness and Sunshine, which are important factors in the consideration of climate as affecting our comfort. This contains statements of average cloudiness, number of clear or cloudy days, times of sunrise and sunset and length of twilight, monthly and annual, number of days with one hour or more of sunshine, dark days, and effect of these changes on temperature and relative humidity.

Part V pertains to Wind Direction and Velocity, with tables of prevailing wind direction, monthly and annual; total wind movement, monthly and annual; greatest daily wind movement; heavy storm winds, comparison of wind velocity, here and at other cities; summary of wind data, and about two and one-half pages are given to tornadoes, frequently misnamed cyclones, which are but infrequent visitors to Chicago.

Part VI takes the subject of Barometric Pressure, its importance and measurement, mean station pressure, monthly and annual, mean departure from normal, highest and lowest pressures, etc.

Part VII relates to Storm Tracks, average and selected, with cold waves and hot waves. The illustrations of these in their movement across our country forms an interesting study.

The Conclusion, in Part VIII, contains an interesting summary of the preceding and is followed by sundry appendices as weather of holidays, journal entries of the weather at the Chicago Fire in 1871, etc., etc. The book is of great interest, has been carefully prepared, and is worthy of study and subsequent reference. The University of Chicago Press is to be commended for publishing such a valuable work.

TREATISE ON GENERAL AND INDUSTRIAL ORGANIC CHEMISTRY, by Dr. Ettore Molinari, Professor of Industrial Chemistry, Luigi Bocconi Commercial University, Milan. Translated from the second enlarged and revised Italian edition by Thomas H. Pope, University of Birmingham. P. Blakiston's Son & Co., Philadelphia. 1913. Cloth; 6 by 9½ in.; 506 illustrations; pp. 770, including index.

This is a work of undoubted value to the manufacturer and technical chemist as well as the student. As the name indicates, the book comprises an outline of general organic chemistry along with the technology of the principal industries based on that science.

The opening pages are devoted to a general discussion of the processes involved in organic chemistry; they contain some useful information on manipulation, and are followed by a short, clear explanation of the general properties of organic compounds, such as isomerism, metamerism, tautomerism, etc.

After the general part comes a detailed account of the most important compounds with their industrial applications.

Especially to be commended are the articles on gas, soap, sugar, and the carbohydrates, alcohol, explosives and textiles. These articles not only describe the process in use, but also take up the machinery in some detail.

A feature of particular interest and value is presented by the statistics of the exports and imports of the most important organic preparations by the principal countries of the world. These statistics are fairly complete and are brought up to date for the years 1910 and 1911 in most cases.

O. J. B.

Hand Book of Construction Plant. Its Cost and Efficiency. By Richard T. Dana. The Myron C. Clark Publishing Co., Chicago. 1914. Flexible leather; 4½ by 7 in.; pp. 702; over 300 illustrations and many tables. Price $5.00.

A very valuable addition to the library of the engineer-contractor or any contractor for that matter.

To the general contractor obliged to make a bid on short notice on a job covering many different kinds of work, it is especially valuable. Here he will find fully described and illustrated the latest and best types of machinery adapted to the job in question, together with data on cost and capacity.

Methods of doing work are changing from day to day and the man who clings to the old ideas is surely doomed to failure.

The author says in his introductory chapter: "The contractor of long experience who applies to his work, even in its simplest operations such as moving earth by scrapers, the methods that he knows absolutely were the best ten years ago, is competing, whether he knows it or not, with men who have developed up-to-date methods that are very likely to be twenty, thirty or even forty per cent more efficacious or economical than the best old ones."

Arranged in alphabetical order the book covers a multiplicity of different kinds of work and outfit from air compressors to wheelbarrows. It is not in any sense an advertising medium for any machine or method, but rather a discussion of the best methods to be followed and the best types of machinery to be used. Cost data from various sources, unit costs of materials and labor in different parts of the country, tables of various sorts, are given in connection with every subject treated.

The author's aim has evidently been to produce a work of practical use.

W. T. K.

LIBRARY NOTES

The library committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts the following publications have been received:

NEW BOOKS.

Myron C. Clark Publishing Co.:
  Hand Book of Construction Plant, Richard T. Dana. Leather.
John Wiley & Sons, Inc.:
  Strength of Materials, H. E. Murdock, 2nd Edition. Cloth.

MISCELLANEOUS GIFTS.

New York Board of Water Supply:
  Eighth Annual Report, 1913. Cloth.
Lyman E. Cooley, M. W. S. E.:
  The Illinois River, Physical Relation and Removal of the Navigation Dams. Cooley. Pam.
Board of Supervising Engineers, Chicago Traction:
  Fifth Annual Report for period ending January 31, 1912. Cloth.
S. E. Hendricks Co., Inc.;
  Hendricks Commercial Register, 1914. Cloth.
R. B. Dole:
  Hypothetical Combinations in Water Analysis. Dole. Pam.
Philadelphia Department of Public Works:
  Annual Report of Director for 1913. Pam.
Hine Brothers:
  American Electro-Magnetic Telegraph. Pam.
New York City Department of Bridges:
  Annual Report, 1913. Cloth.
Chicago Department of Public Works:
  38th Annual Report, 1913. Cloth.

E. E. R. Tratman, M. W. S. E.:
Illinois Geological Survey, Monograph I, Mississippian Brachiopoda, Text and Plates. Cloth.

EXCHANGES.

Society for the Promotion of Engineering Education:
Proceedings, 21st Annual Meeting, June, 1913. Cloth.
Canada Commission of Conservation:
Conservation of Coal in Canada. Cloth.
Trent Watershed Survey. Cloth.
Fur Farming in Canada. Cloth.
Bureau of Railway Economics:
Five Lectures Concerning Transportation, L. G. McPherson. Pam.
New York Public Service Commission, 1st District:
Annual Report, 1912, Vol. II. Cloth.
New Orleans Sewerage and Water Board:
28th Semi-Annual Report, December 31, 1913. Pam.
Boston Society of Civil Engineers:
Year Book, 1914-15. Pam.
Canada Department of Mines:
Summary Report for 1912. Pam.
Ohio State Board of Health:
27th Annual Report, 1912. Cloth.
Royal Society of New South Wales:
Journal and Proceedings, 1913, Part II. Paper.
Connecticut Society of Civil Engineers:
Proceedings, 1914. Paper.
Manchester, N. H., Board of Health:
Annual Report, 1913. Pam.
Baltimore Sewerage Commission:
Annual Report, 1913. Paper.
Western Australian Institution of Engineers:
Proceedings, November, 1913. Pam.
Illinois State Water Survey:
Report for Year Ending December 31, 1912. Cloth.
Iowa Engineering Society:
Proceedings, 26th Annual Meeting, 1914. Paper.
International Railway Fuel Association:
Proceedings 6th Annual Convention, 1914. Paper.
McGraw Publishing Co.:
Electric Railway Directory, August, 1914. Lea.
Canadian Society of Civil Engineers:
Transactions, October to December, 1913. Paper.
Lake Superior Mining Institute:
Advance copies of papers to be read at meeting of Aug. 31—Sept. 3rd.
Association of Transportation and Car Accounting Officers:
Proceedings, June, 1914. Paper.
Canada Department of the Interior:
Report of the Director of Forestry, 1913. Pam.
Timber Conditions in the Little Smoky River Valley and Adjacent Territory. Pam.
Timber and Soil Conditions in Southeastern Manitoba. Pam.
Canada Department of Mines (Geological Survey):
Mother Lode and Sunset Mines, Boundary District, B. C. Pam.
Clay and Shale Deposits in the Western Provinces. Pam.
Museum Bulletin No. 2. Pam.
The Archæan Geology of Rainy Lake, Restudied. Pam.
Kewagama Lake Map-Area, Quebec. Pam.

Canada Department of Mines (Mines Branch):
Moose Mountain Iron Bearing District, Ontario. Pam.
Magnetite Occurrences Near Calabogie, Renfrew Co., Ontario. Pam.
Kansas Engineering Society:
Transactions and Report of Sixth Annual Meeting, 1914. Pam.
American Electrochemical Society:
Transactions, Vol. 25, 1914. Paper.
Engineers' Club of Philadelphia:
Directory, 1914. Leather.
Association of Ontario Land Surveyors:
Annual Report and Proceedings of Twenty-second Annual Meeting, 1914. Paper.
University of Texas:
Bulletin No. 363, The Deep Boring at Spur. Pam.
New Jersey State Board of Health:
Thirty-seventh Annual Report, 1913. Cloth.
Brooklyn Engineers' Club:
Proceedings, 1913. Cloth.
Bureau of Railway Economics:
Statistics of Railways,- 1900-1912. Pam.
Institution of Civil Engineers:
Minutes of Proceedings, Vol. 195, July, 1914. Paper.
List of Members, Charter, etc., 1914. Paper.
Institution of Naval Architects:
Transactions, 1914. Cloth.
Wisconsin Geological and Natural History Survey:
The Inland Lakes of Wisconsin. Cloth.
Engineers' Society of Western Pennsylvania:
List of Members, 1914. Pam.
American Society of Agricultural Engineers:
Transactions, 1912-1913. 2 paper.
Franklin Institute:
Year Book, 1914. Pam.
University of Wisconsin:
Bulletin No. 672, The Diaphragm Method for Measurement of Water in Open Channels of Uniform Cross-section. Pam.
American Society of Mechanical Engineers:
Transactions, 1913. Half leather.
New York Public Service Commission, First District:
Proceedings, 1913. Cloth.
Michigan Engineering Society:
Proceedings, 1914. Paper.
University of Illinois Engineering Experiment Station:
Bulletin No. 75, Thermal Properties of Steam, G. A. Goodenough. Pam.
West Virginia Geological Survey:
County Reports, 1914, Preston County. Text and Maps. Cloth.
Vermont State Geologist:
Report for 1912. Boards.
Providence, R. I., City Engineer:
Annual Report, 1913. Pam.

MEMBERSHIP

Additions:

Engh, Harry M., Milwaukee, Wis	Associate Member
Winetz, Aaron J., Chicago	Member

VOL. XIX, No. 9. NOVEMBER, 1914

JOURNAL
OF THE
WESTERN SOCIETY
OF
ENGINEERS

CONTENTS

Permeability Tests on Gravel Concrete.
Morton O. Withey 813
Discussion:
By E. H. Lee, W. H. Finley, J. H. Libberton, E. B. Wilson and F. E. Davidson.
Arithmetical Machines.
H. E. Goldberg 859
Reactions in a Three-Legged Stiff Frame with Hinged Column Bases.
N. M. Stineman 881
Discussion:
By J. J. Richey, F. E. Vey, T. A. Smith, M. D. Kolyn.
Memorials.
Barnabas Schreiner 921
William H. Pratt 922
Proceedings of the Society. Minutes of Meetings 924
Book Reviews 925
Library Notes 930
Membership 932
Index to Advertisers xxii

CHICAGO
Published Monthly, Excepting July and August, by the Society,
1735 Monadnock Block.

Entered as Second-Class Matter March 2, 1896, at the Postoffice at Chicago, Ill., under Act of March 3, 1879.

Subscription Price, $3.00 per Volume of Ten Numbers.

50 Cents a Single Number.

Copyright, 1914, by the Western Society of Engineers.

WESTERN SOCIETY OF ENGINEERS

1735 Monadnock Block, Chicago, Illinois.
Phone Harrison 945.

OFFICERS FOR 1914

President	E. H. Lee, Dearborn Station
First Vice-President	B. E. Grant, Room 207 City Hall
Second Vice-President	Ernest McCullough, 501 Monadnock Block
Third Vice-President	G. F. Gebhardt, Armour Institute
Treasurer	C. R. Dart, Room 700, 900 Michigan Ave.
Trustee	J. G. Giaver, 1 year, 1417 Railway Exchange
Trustee	F. E. Davidson, 2 years, 1448 Monadnock Block
Trustee	H. S. Baker, 3 years, 402 City Hall

Past Presidents on the Board of Direction.

O. P. Chamberlain	108 So. La Salle St.
W. C. Armstrong	226 W. Jackson Blvd.
Albert Reichmann	208 So. La Salle St.

ELECTRICAL SECTION

Executive Committee

F. J. Postel, Chairman; H. M. Wheeler, Vice-Chairman

G. T. Seely	1 year
P. B. Woodworth	2 years
E. W. Allen	3 years

BRIDGE AND STRUCTURAL SECTION

Executive Committee

J. H. Prior	Chairman
J. W. Musham	Vice-Chairman

E. N. Layfield H. C. Lothholz I. F. Stern

HYDRAULIC, SANITARY AND MUNICIPAL SECTION

Executive Committee

W. D. Gerber	Chairman
G. C. D. Lenth	Vice-Chairman

W. W. DeBerard Douglas Graham Langdon Pearse

Secretary............J. H. Warder

The Chanute Medals

The Board of Direction, W. S. E., desire to announce that the Octave Chanute Medals will be awarded for the most meritorious papers on Engineering subjects presented before this Society by members thereof during the year 1914.

Journal of the
Western Society of Engineers

VOL. XIX NOVEMBER, 1914 No. 9

PERMEABILITY TESTS ON GRAVEL CONCRETE

MORTON O. WITHEY*

Presented September 14, 1914.

This paper is a partial report on tests which are being conducted at the University of Wisconsin to determine the permeability of concrete to water. These experiments were started in the spring of 1912 at the suggestion of the Inspection Bureau of the Universal Portland Cement Company. The particulars in the method of conducting the tests which make them somewhat unique are the use of machine-mixed concrete, the employment of large specimens having a prescribed volume of concrete subjected to water pressure, and the measurement of the water entering the specimens during a large number of hours. The proposed program of experiments includes tests with different brands of cement on broken stone and sand, broken stone and screenings, and gravel and sand aggregates. Only the tests on the latter combination with one brand of cement are herein considered, although work is now being done on mixes containing sand and broken stone. The reported tests include the effects on permeability of the following variables: age, thickness and consistency of concrete; time of mixing; gradation of the aggregate; wet and dry sand; fineness of cement; and curing conditions.

Materials. Universal Portland cement was used in all the tests herein described. In order to insure against variations in the property of the cement, two fifty-barrel lots were selected from a local supply, mixed separately and stored in bulk in galvanized iron grain bins. To make these bins as tight as possible, all seams were calked with tar and the edge of the door was lined with heavy felt. Table 1 contains the results of the physical tests made on the two binfuls, designated P_1 and P_2. Lot P_1 was used in specimens numbered below 296; lot P_2 in the remainder. The loose weight per cubic foot of cement was considered to be 100 pounds.

Pit sands Sd_1P, furnished by Clark and Fisher, and $Sd_{12}P$, $Sd_{13}P$ and $Sd_{14}P$, furnished by the Janesville Sand and Gravel

---

*Assistant Professor of Mechanics, University of Wisconsin.

Company, were obtained from Janesville, Wisconsin; Sd_2P was gotten from the Waukesha Lime and Stone Company, Waukesha, Wisconsin. The weights per cubic foot (measured loose), the specific gravities and the chemical analyses for these sands are given in Table 2. Figure 1 shows the mechanical analysis curves for these sands. An idea of the character of the grains and further information on the gradation of sizes may be gotten from Fig. 3. The latter illustration also shows the three sizes into which the sands were divided for the graded sand mixes.

Gravel Gl_1P came from the pit of the Janesville Sand and Gravel Company and Gl_2P was supplied by the Waukesha Lime and Stone Company. Information similar to that given for the sands is supplied for the gravels by Table 2 and Figs. 1 and 4. Figs. 1 and 2 also show the mechanical analysis curves for the graded mixes.

TABLE NO. 1

PHYSICAL PROPERTIES OF UNIVERSAL PORTLAND CEMENT

Mix	Tensile Strength			Residue on Sieves-%		Time of Set		Soundness			*Specific Gravity
	Age in Days	Mix				Initial	Final				
		Neat lb/in²	1:3 Standard Sand lb/in²	No. 100	No. 200	hr.-min.	hr.-min.	Air	Water	Steam	
P_1	7	647	201	2.3	20.3	1 57	7 22	O.K	O K	O.K	3.02
	28	779	304								
	60	697	340								
	180	728	358								
	360	647	266								
P_2	7	680	283	3.0	21.8	1 40	5 40	O.K	O.K		3.03
	28	735	338								
	60	671	364								
	180	772	359								
	360										
†P_2	7	646	260			1 36	4 00	O.K	O.K.		
	28	572	357								
	60	644	348								
‡P_1G	7		332		5.5						
	28		404								

* Samples were not dried
† Tested after storing in bulk 1 yr and 11 mo in a tight galvanized iron bin
‡ Cement was reground in a ball mill

Forms of Specimens. Several forms of specimens were experimented upon before the *PU* type shown in Figs. 5 and 6 was adopted. In molding these test-pieces, both mortar shell and concrete core were cast at the same time in a manner which will be later described. It will be noted that the area of the core in these specimens was one square foot, consequently the leakages read were in terms of this unit of area. This type of specimen was found very satisfactory for most of the tests made. To determine the water-tightness of the 1:1 mortar shells, specimens were made with a building paper covering over the interior surface of the core. The latter was also made of 1:1 mortar. At an age of 21 days 0.0022 gallon of water entered one of these specimens in 304 hours. Under the same conditions only 0 0003 gallon entered the other; a third specimen four months old showed no leakage for the same period. However, when subjected to very rapid drying in curing, it was found, in some cases, that the mortar shells cracked circumferentially in the plane of the lower edge of the castings. Moreover, it was impossible, with this form of test-piece, to determine the permeability of concrete with the pressure applied perpendicular to the direction of pouring.

TABLE NO. 2

PROPERTIES OF AGGREGATES

Aggregate	Wt per Cu. Ft.	Specific Gravity	% Absorption	Chemical Analysis - %					
				SiO_2	CaO	MgO	Al_2O_3 + Fe_2O_3	Loss on Ignition	Total
Sd_1P	112.2	2.70		49.76	13.70	7.74	5.73	19.22	96.15
Sd_2P	112.0	2.77	0.29	17.20	24.52	18.58	4.36	35.42	100.08
$Sd_{12}P$	104.5	2.66	0.19	61.89	10.72	6.58	5.54	14.21	98.94
$Sd_{13}P$	108.2	2.66	0.19	61.89	10.72	6.58	5.54	14.21	98.94
$Sd_{14}P$	109.7	2.66	0.19	61.89	10.72	6.58	5.54	14.21	98.94
Gl_1P	109.3	2.74	0.63	21.72	23.54	14.54	5.02	34.87	99.69
Gl_2P	107.3	2.80	1.40	10.20	27.36	15.43	3.30	38.91	95.20

To secure some information regarding the effect of direction of flow with respect to the direction of pouring, two other types of specimens, *PUL* and *PUHC* in Fig. 5, were also tested. The *PUL* type of specimen has the same area of concrete exposed to water pressure and to air, but apparently the shrinkage strains encountered in casting render it very difficult to secure sound specimens. The *PUHC* specimens have the advantage of being much easier to mold than the *PUL* specimens. In the former, however, the area exposed to water pressure is considerably less than that exposed to air.

Methods of Making Specimens. In general, the sand was spread out in a thin layer on the floor of the mixer house and

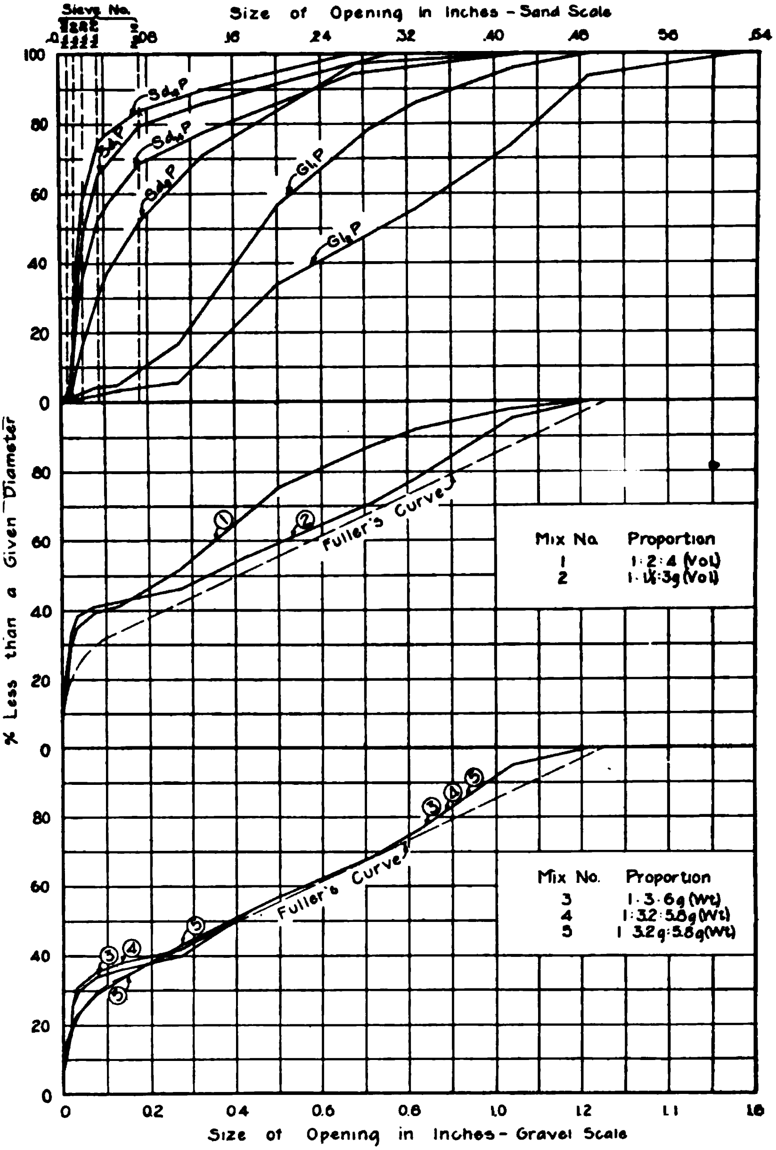


Fig 1 — Mechanical Analysis Curves for Aggregates and Mixes No. 1 to 5

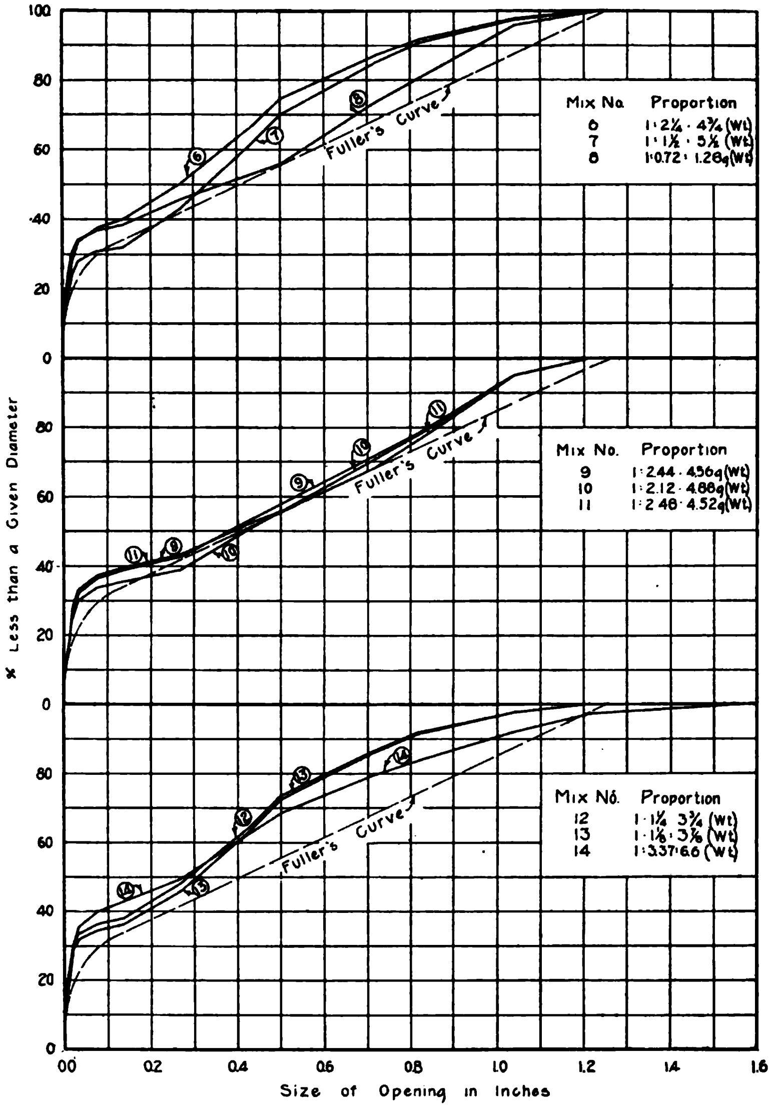
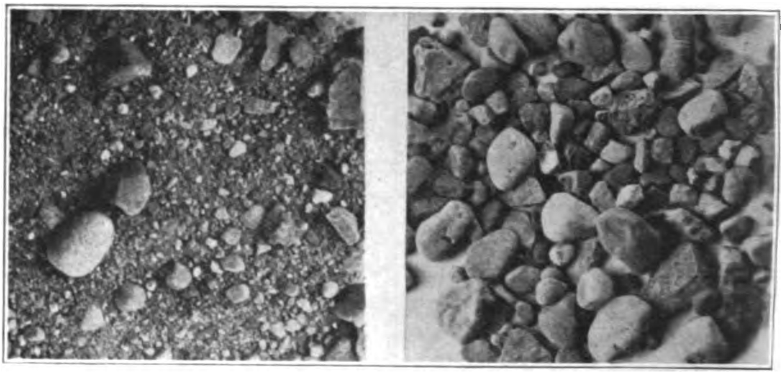
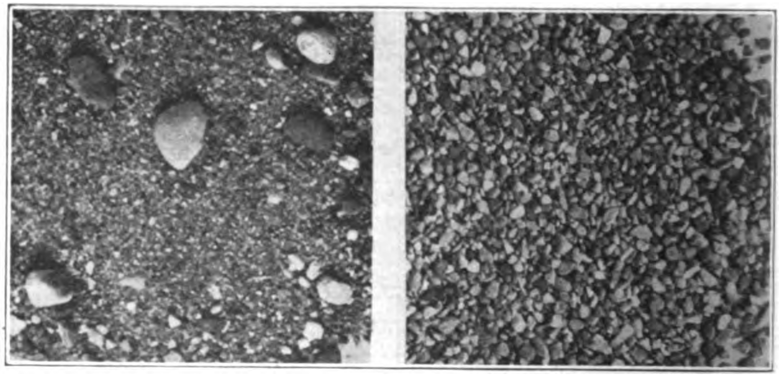


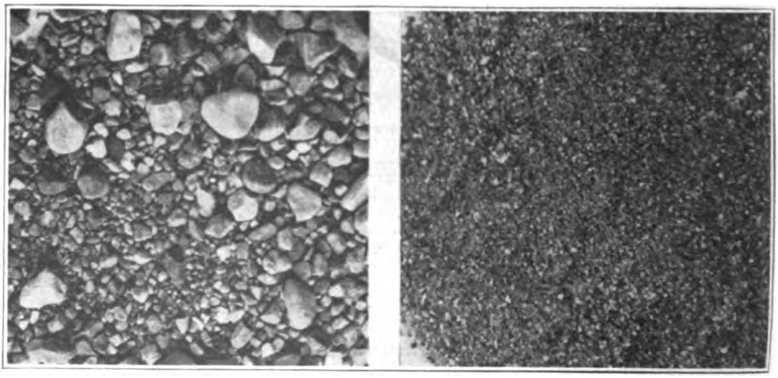
Fig 2 — Mechanical Analysis Curves for Mixes No. 6 to 14



$Sd_{14}P$. No. 20 to ¼-Inch Mesh.



$Sd_{12}P$. No. 20 to 10 Mesh.



Sd_2P No. 0 to 20 Mesh.

Fig. 3.—Natural and Artificially Graded Sands (Full Size).

allowed to dry for one or two days before mixing. Ordinarily the particles of gravel also were dry on the surface when concrete was made. For most of the tests the moisture content in the aggregate was determined and allowance made for it in computing the percentage of water.

The measurements of all quantities of materials were made by weighing. Both proportions by volume and by weight were employed. By loose volume, proportions 1:1½:3 and 1:2:4 were most commonly employed; tests on one batch of 1:3:6 proportions are also reported. In proportioning by weight, 1:5, 1:7 and 1:9 mixes of cement and aggregate were tested. Of these mixes, the last was experimented with most. The determinations of the proper proportions of sand and gravel for proportions by weight were made by two methods, either by volumetric tests from which the proportions producing the maximum strength and density were ascertained, or by combining the mechanical analysis curves of the cement, sand and gravel so that the curve of the combination would approach the theoretical curve advocated by Fuller and Thompson.* For grading the aggregate a Converse rotary screen set at a slope of ½ in. per ft. and run at a speed of 11 r. p. m. was employed. It separates the gravel into the following sizes: 0 to ¼, ¼ to ½,

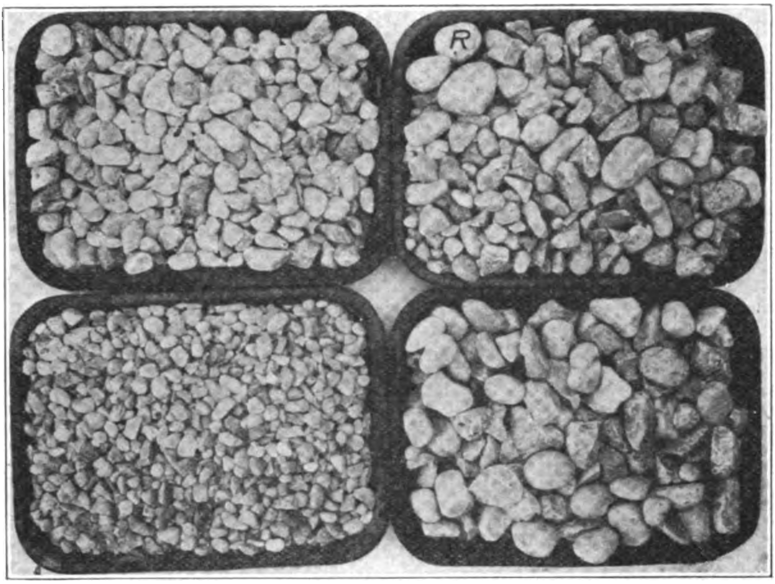
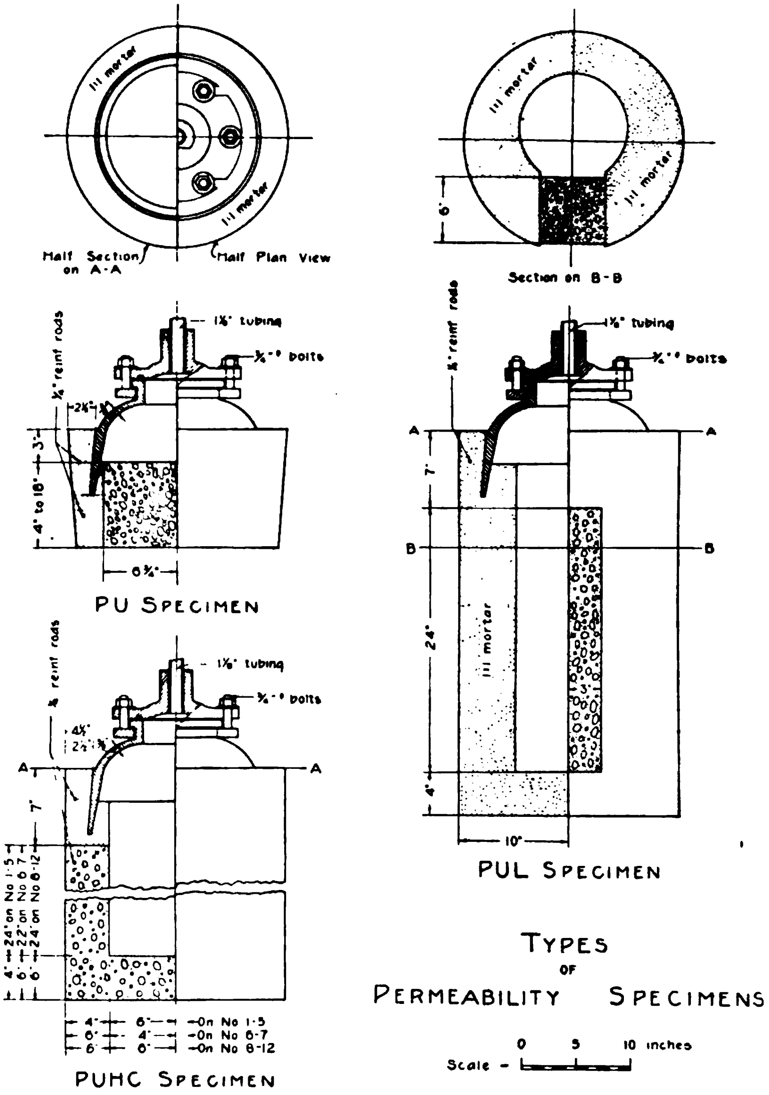


Fig. 4.—Janesville Gravel—R, as Received and the Three Sizes Used in Graded Mixes. (Reduced 6:1.)

---

*Concrete, Plain and Reinforced, p. 202.



TYPES OF PERMEABILITY SPECIMENS

Fig 5

½ to ¾, ¾ to 1¼ inches. Sand was graded by hand-screening on riddles.

In recording proportions the letter "g" after a number signifies that the aggregate was mechanically graded. For example: 1:3:6g means that one part cement, three parts of pit-run sand and six parts of graded gravel were used.

Nearly all of the concrete was mixed in a No. 0 Smith mixer which was run at 28 to 30 r. p. m. For most tests the dry materials were discharged directly from the hopper cart, in which they were measured, into the mixer which had been wetted with sufficient water to cover the inside surface. After mixing one-half minute dry, the proper addition of water was admitted through the spout and hopper of the machine at the rate of 350 lbs. per minute and the mixing continued for one and one-half minutes. In general, a medium consistency which could be easily puddled with

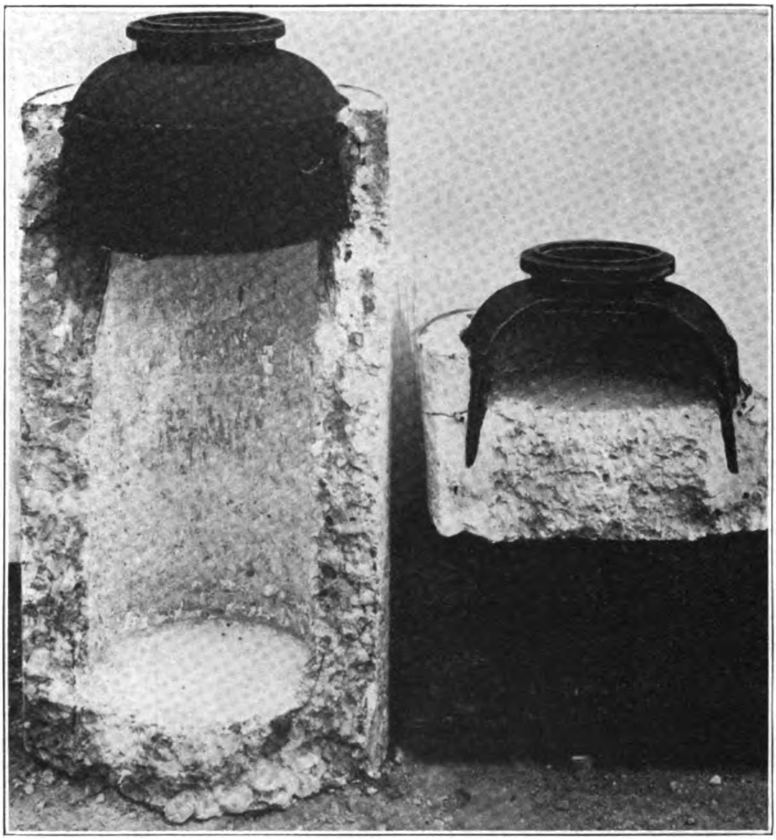


Fig. 6.—Longitudinal Sections of PU and PUHC Specimens.

a rod and which would barely flow from the shovel was employed. On completion of the mixing period the concrete was rapidly dumped into wheelbarrows. Care was taken to allow plenty of time for the mortar adhering to the inside of the mixer to drop out. Figure 7 shows the appearance of a batch of 1:9 concrete of medium or mushy consistency. Figure 8 shows the same mix after it had been molded into a 6-in. cylinder 12 in. high, and the mold immediately slid upward.

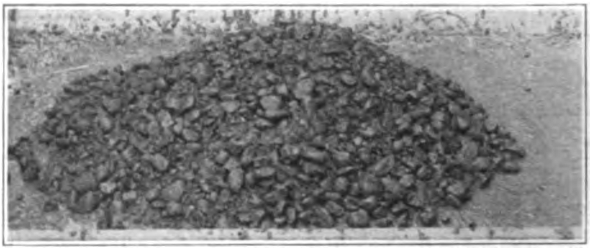


Fig. 7.—A 1:9 Batch of Medium Consistency.

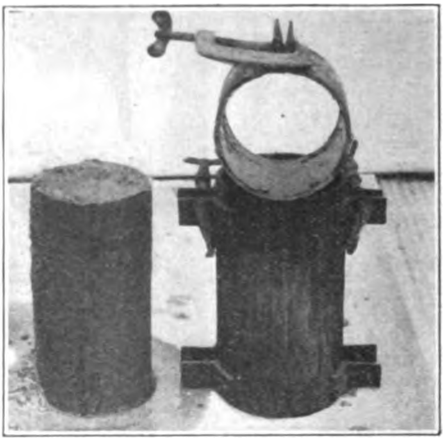


Fig. 8.—The Appearance of a 6 by 12 Inch Cylinder of 1:9 Concrete of Medium Consistency. Mold Removed Immediately After Casting.

Hand mixing was done on metal trays. The gravel was spread in a thin layer over the tray, covered with the sand and mixed by two men with square-pointed shovels. The mixed aggregate was then spread out, covered with gravel, and again mixed. Next a crater was formed in the mass, the proper amount of water added, and the mixing finished. In most cases seven turns of the pile were given after each material was added, twenty-one turns in all. From the results of both compression and permeability tests, it is thought that such hand mixing was equivalent to that done by the machine.

The 1:1 mortar for the shells on the specimens was thoroughly mixed by hoe in a metal tray at the same time as the concrete was being made. A soft consistency, which, when formed into a cone 6 in. high and 3 in. in diameter, flattened on removal of the mold to a height of approximately 2 in., was used.

The molds for the *PU* specimens were assembled as shown in Fig. 9 (*a*). The dome-shaped bonnets (*b*) were set neck down upon the cast iron pedestals (*c*). Damp sand was then firmly tamped into the bonnets and leveled off at a depth of 3 in. below the upper rim of the bonnet. On top of the sand a layer of parchymore paper was placed to prevent the mortar from running into it. The specimens were made as rapidly as possible after the concrete was mixed. In making the *PU* specimens, the shells were molded by tamping layers of mortar between the outer and inner molds, Fig. 9 (*a*). A 3-in. layer of concrete, composed of equal portions from each wheelbarrowful, was then placed, the interior cylinder raised, and the concrete thoroughly puddled so that a good union between shell and core was obtained. This process was continued until the mold was filled. A cement sack soaked with water was then put over the top of the specimen. Figure 10 shows the appearance of the cross-sections of several *PU* specimens, and furnishes an indication of the uniform shape and size of the cores in the test-pieces.

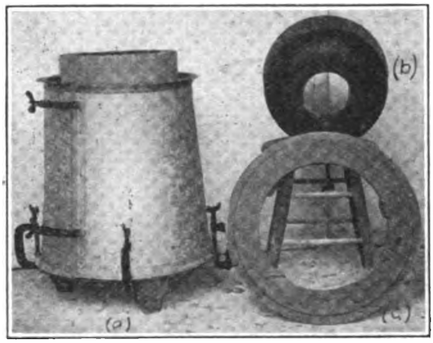


Fig. 9.—Molds for Permeability Specimens.

Two or three compression cylinders 6 in. in diameter and 18 in. long were generally made with each batch of concrete.

Curing. On the day following the pouring, the tops of *PU* specimens and the outside surfaces of all others were chipped and scrubbed with wire brushes to remove laitance and rich mortar. In general, *PU* specimens remained in the molds two days. The sand was then removed from the castings and the interior surface of the concrete thoroughly chipped with a heavy steel bar provided with a chiseled end. Figure 11 shows typical appearance of bottoms and interiors of *PU* specimens. Figure 6 also illustrates the interior and exterior of *PUHC* 3. Molds were removed from *PUL* and *PUHC* specimens after one day and the outsides of the test-pieces covered with wet sacks. The interior surfaces of the concrete on *PUL* specimens were chipped when the specimens were two to five days old. The interiors of *PUHC* specimens 1 to 7 were chipped during the second week after making; the interiors of the other *PUHC* specimens were chipped after four or five days.

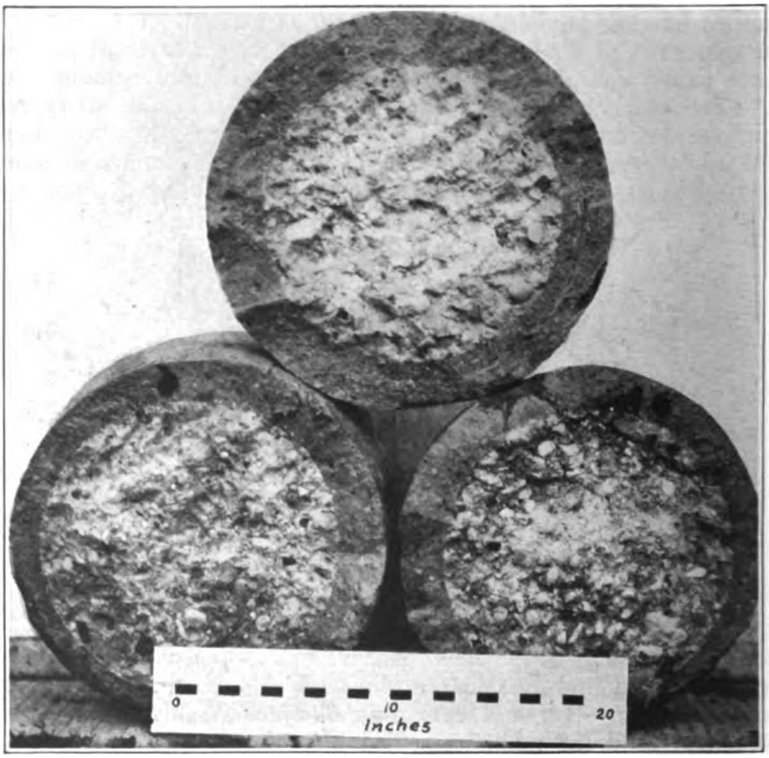


Fig. 10.—Cross Section Fractures of PU Specimens, Showing Concrete Cores and Mortar Shells.

Normally, the interiors of all specimens were filled with water and the sack coverings kept wet by sprinkling every morning and night excepting Sunday, when specimens were sprinkled once only. A number of specimens were removed from the molds to the hall in the laboratory where they dried until tested. Several specimens after normal curing were dried in a gas oven at comparatively low temperatures for several days. Such specimens were heated during the day time only and the oven was regulated so that a temperature of 150 to 170 deg. Fahr. was reached in about two or three hours.

Compression cylinders were, in general, subjected to the same curing conditions as the permeability specimens with which they were cast.

Testing. Before testing, the specimens were washed out, placed beneath the permeability tubes shown in Fig. 12 and filled with city water. In testing all *PU* specimens numbered above 167, 5 lbs. of damp Janesville sand was spread over the interior of each specimen before filling to serve as a filter. No sand filter was used in either *PUL* or *PUHC* specimens. After the gaskets had been inserted in grooves in the flanges and the castings had been bolted to the apparatus, city water was forced into the tubes as shown at *p*, Fig. 12, until they were nearly full. Air pressure from the storage tank, *r*, was then admitted through the copper tubing, *c*,

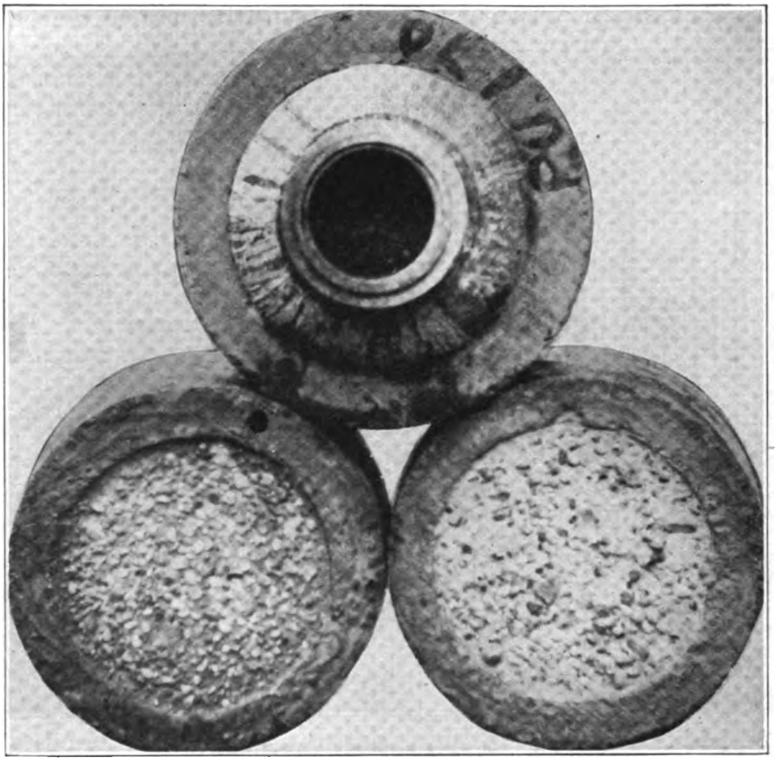


Fig. 11.—Appearance of Surfaces of PU Specimens After Cleaning.

and valves, *v*. By means of the targets, *t*, on the water gauges, the height of the water in the tubes was read on the scales, *s*. The scales on the long tubes were graduated to read 0.001 gallon, those on the short tubes read to approximately 1¼ cubic centimeters. By using the targets, readings could readily be estimated to 1/10 division on either apparatus. Ordinarily readings were taken at one-half hour after the pressure was admitted, then in perhaps one or two hours, and twice a day thereafter. From time to time observations were also made upon the appearance of the bottoms of the specimens. Insofar as possible, specimens were run for a period of fifty hours or more at approximately constant pressure.

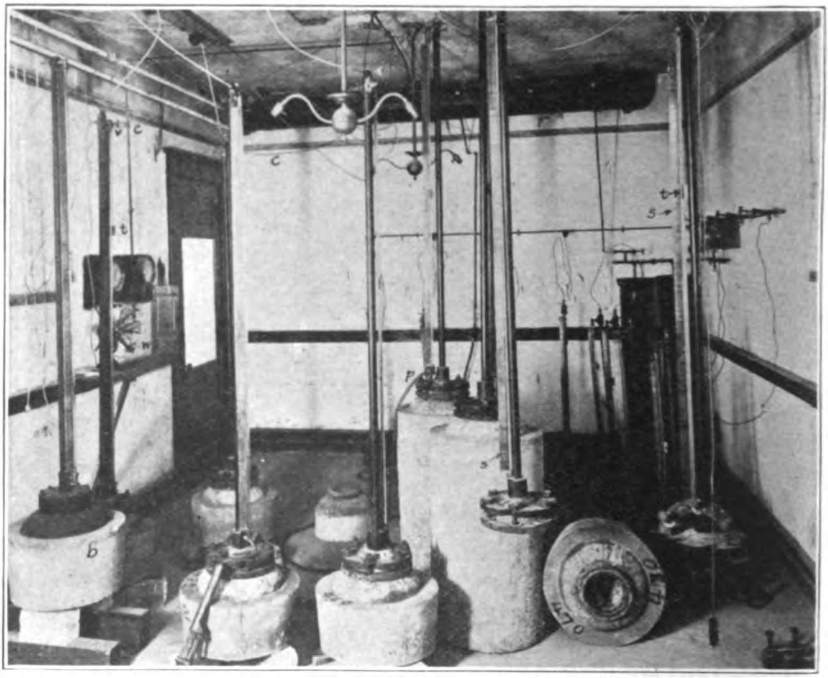


Fig. 12.—Permeability Apparatus.

Most of the specimens were tested at one age and under one pressure; exceptions are indicated in the tables.

A blank specimen, *b*, Fig. 12, which consisted of a dome-shaped casting tightly sealed at the bottom by a welded steel plate and encased in a mortar shell like the *PU* specimens, was read each time readings were taken on the test-pieces. By means of this device corrections could be made for changes in the heights of the water columns produced by causes other than leakage.

Wet and dry-bulb thermometers were also read twice a day.

The fan shown at *w*, Fig. 12, furnished a draught of air about the wet-bulb thermometer. During cold weather when the room was heated by steam, the humidity varied between 20 and 50 per cent. In the summer it was generally above 70 per cent.

Computations. For the most part, curves were drawn with time as abscissa and heights of water column as ordinates for both the individual specimens and the blank at the time observations were taken. Average time-leakage curves corrected for the blank readings were then plotted on the same sheet with the individual curves. These will be herein referred to as time-leakage curves. In most of the tables each result is the average of tests on four specimens. To facilitate the tabulation of data and to give some idea of the change in rate of flow, the average rates of flow for periods 0 to 50, 20 to 50 and 40 to 50 hours were adopted. Although leakages over a much greater period of time were determined for many specimens, only a few of the long-time records will be included in this paper. In Tables 8 and 10, the per cent variation for the 40-50 hour period was obtained by dividing the difference between the maximum and minimum leakages for this period by the average leakage and multiplying by one hundred.

In computing the data from tests on the *PUHC* specimens, the rate of flow was divided by the average area in square feet of the inside and outside surfaces of concrete in order to express the quantity in terms of unit area.

The water pressures recorded in the tables were averaged from the recorded gage pressures and include the pressure due to the average height of the water column in the permeability tubes.

In the remarks columns of the various tables, *L* indicates that water was dripping from the bottom of the specimens mentioned, *M* indicates that the bottoms were moist, *D* indicates that the bottoms were discolored, *SL* means that water leaked through the shells. Thus 260, 262, 263—*M;* 261*L,* means that specimens 260, 262, 263 were moist and 261 was leaking during the test considered. The absence of any note indicates that there was no visible evidence of leakage on the bottoms of the specimens.

Properties of Specimens. Table 3 contains a list of the 294 specimens reported upon in this paper and data concerning constituent materials, proportions, method of mixing, and thickness. Of the above number, 88 were of 1:1½:3 and 67 of 1:2:4 proportions by volume; 98 were of 1:9 proportions by weight.

Effect of Age on Permeability. Table 4 contains the results of tests on 1:2:4 concrete at various ages up to one year. Average leakage-time curves for specimens of different ages appear in Fig. 13. Excepting specimens 260-263, none of the test-pieces showed visible signs of leakage. Nevertheless, from evidence which will be presented and from a comparison of the rates of flow at the early ages it seems certain that the water went through the speci-

TABLE NO. 3

PROPORTIONS METHODS OF MIXING AND THICKNESSES OF SPECIMENS USED

Batch No	Spec. No	Materials			Proportions of Gravel by Wt				*Nominal Proportions				Mech. Analysis Curve No	Method of Mixing			Thickness of Specimens inches
														Machine		Hand	
														Time min		No. Turns	
		Cement	Sand	Gravel	0-¼	¼-½	½-¾	¾-1¼	Cement	Sand	Gravel	Prop'tn by		Dry	Wet		
8	100-103	P.	Sd,P	Gl,P					1	1½	3	V		½	2½		4
9	104-107	P.	Sd,P	Gl,P					1	1½	3	V		½	2½		8
10	108-111	P.	Sd,P	Gl,P					1	2	4	V	1	½	2½		6
11	112-115	P.	Sd,P	Gl,P					1	2	4	V	1	½	½		6
12	116-119	P.	Sd,P	Gl,P					1	2	4	V	1	½	9½		6
14	124-127	P.	Sd,P	Gl,P					1	1½	3	V		½	1½		6
15	128-131	P.	Sd,P	Gl,P					1	1½	3	V		½	1½		12
16	132-135	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		4
17	136-139	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		8
18	140-143	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		18
19	144-145	P.	Sd,P	Gl,P					1	2¼	4¾	W	6			21	6
20	146-147	P.	Sd,P	Gl,P					1	1½	5½	W	7			21	6
22	150-151	P.	Sd,P	Gl,P	0.98	060	1.08	1.62	1	0.72	4.28g	W	8			21	6
23	152-153	P.	Sd,P	Gl,P					1	1¼	3¾	W	12			21	6
24	154-155	P.	Sd,P	Gl,P					1	1⅛	3⅞	W	13			21	6
26	160-163	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		6
27	164-167	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		12
31	180-183	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		4
32	184-187	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		8
33	188-191	P.	Sd,P	Gl,P					1	1½	3	V		½	1½		4
34	192-195	P.	Sd,P	Gl,P					1	1½	3	V		½	1½		8
39	212-215	P.	Sd,P	Gl,P					1	1¼	3¾	W	12	½	1½		8
41	220-223	P.	Sd,P	Gl,P					1	1½	3	V		½	1½		12
44	232-235	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		6
45	236-239	P.	Sd,P	Gl,P					1	2¼	4¾	W		½	1½		18
46	240-243	P.	Sd,P	Gl,P					1	2¼	4¾	W		½	1½		4
48	248-251	P.	Sd,P	Gl,P		1.12	1.12	2.32	1	2.44	4.56g	W	9	½	1½		8
49	252-255	P.	Sd,P	Gl,P		1.28	1 20	2.40	1	2.12	4.88g	W	10	½	1½		8
50-1	256-263	P.	Sd,P	Gl,P					1	2	4	V	1	½	1½		6
52	264-267	P.	Sd,P	Gl,P					1	3	6	V	14	½	1½		8
55	276-279	P.	Sd,P	Gl,P		1.65	1 15	3.20	1	3	6g	W	3	½	4½		6
56	280-283	P.	Sd,P	Gl,P		1.65	1 15	3.20	1	3	6g	W	3	½	½		6
57	284-287	P.	Sd,P	Gl,P		1.65	1.15	3.20	1	3	6g	W	3	½	1½		6
59	292-295	P.	Sd,P	Gl,P		165	1 15	3.20	1	3	6g	W	3	½	1½		6
60	296-299	P_2	Sd,P	Gl,P		165	1.15	320	1	3	6g	W	3	½	1½		6
64-5	312-319	P_2	Sd,P	Gl,P		165	1 15	320	1	3	6g	W	3	½	1½		6
66	320-323	P_2	Sd,P	Gl,P		1.65	1.15	3.20	1	3	6g	W	3	½	½		6
68	328-331	P_2	Sd,P	Gl,P		1.65	1.15	3.20	1	3	6g	W	3	½	4½		6
69-0	332-339	P_2	Sd,P	Gl,P		165	1 15	320	1	3	6g	W	3	½	1½		6
71	340-343	P_2	Sd,P	Gl,P		1.65	1.15	3.20	1	3	6g	W	3	½	4½		6
72	344-347	P_2	Sd,P	Gl,P		1.65	1.15	3.20	1	3	6g	W	3			9	6
73	348-351	P_2	Sd,P	Gl,P		1.45	1.15	3.20	1	3.2	5.8g	W	4	½	1½		6
74	352-355	P_2	Sd,P	Gl,P		0.96	1.00	2.56	1	2.48	4.52g	W	11	½	1½		8
75-8	356-371	P_2	Sd_2P	Gl,P		0.75	0.65	1.72	1	1½	3g	V	2	½	1½		6
79	372-373	P_2	$Sd_{12}P$	Gl,P					1	1		W				by hoe	6
80-1	376-383	P_2	Sd_2P	Gl,P		0.75	0.65	1.72	1	1½	3g	V	2	½	4½		6
82	384-387	P_1	Sd_2P	Gl,P		0.75	065	1.72	1	1½	3g	V	2	½	½		6
83	388-391	P_1	$Sd_{11}P$	Gl,P		0.75	0.65	1.72	1	1½	3g	V	2	½	4½		6
84	392-395	P_1	$Sd_{12}P$	Gl,P		0.75	0.65	1.72	1	1½	3g	V	2	½	1½		6
85	397-399	P_2	$Sd_{12}P$	Gl,P		0.75	065	1.72	1	1½	3g	V	2	½	½		6

TABLE NO. 3

PROPORTIONS METHODS OF MIXING AND THICKNESSES OF SPECIMENS USED

Batch No	Spec. No	Materials			Proportions of Gravel by Wt.				*Nominal Proportions				Mech. Analysis Curve No.	Method of Mixing			Thickness of Specimens inches
		Cement	Sand	Gravel	0-¼	¼-½	½-¾	¾-1¼	Cement	Sand	Gravel	Prop'n by†		Machine Time min Dry	Machine Time min Wet	Hand No. Turns	
86¹	400-403	P_1	Sd_2P	G_1P		1.45	1.15	3.20	1	3.2g	5.8g	W	5	½	1½		6
87-8	404-411	P_1	Sd_2P	G_1P		1.65	1.15	3.20	1	3	6g	W		½	4½		6
89	412-415	P_2	Sd_2P	G_1P		0.76	0.65	1.73	1	1½	3g	V	2	½	4½		6
91	418-421	P_2	Sd_2P	G_1P		0.76	0.65	1.73	1	1½	3g	V	2	½	4½		6
92	422-425	P_2	Sd_2P	G_1P		1.65	1.15	3.20	1	3	6g	W		0	¾		6
93	426-429	P_2	Sd_2P	G_1P		1.65	1.15	3.20	1	3	6g	W		0	2		6
94	430-433	P_2	Sd_2P	G_1P		1.65	1.15	3.20	1	3	6g	W		0	5		6
95	434-437	P_2	Sd_2P	G_1P		1.45	1.15	3.20	1	3.2g	5.8g	W	5	½	1½		6
96	PUL 2	P_2	Sd_2P	G_1P					1	1		W		½	1½		
97	PUL 3	P_2	Sd_2P	G_1P		1.65	1.15	3.20	1	3	6g	W		0	¾		6
98	438-441	P_2	Sd_2P	G_1P		0.75	0.65	1.72	1	1½	3g	V	2	0	¾		6
99	442-445	P_1	Sd_2P	G_1P		0.75	0.65	1.72	1	1½	3g	V	2	0	2		6
100	446-449	P_1	Sd_2P	G_1P		0.75	0.65	1.72	1	1½	3g	V	2	0	5		6
101	PUL 4	P_2	Sd_3P	G_1P		0.75	0.65	1.72	1	1½	3g	V		½	4½		6
102-3	454-60-PUL5	P_2	Sd_3P	G_1P		0.75	0.65	1.63	1	1½	3g	V		½	4½		6
104¹	461-464	P_2	Sd_2P	G_1P		1.45	1.15	3.20	1	3.2g	5.8g	W	5	½	1½		6
105¹	PUL 6	P_2	Sd_2P	G_1P		1.45	1.15	3.20	1	3.2g	5.8g	W	5	½	1½		6
106	PUHC1-3	P_2	Sd_3P	G_1P		1.65	1.15	3.20	1	3	6g	W		½	1½		4
107	PUHC45	P_2	Sd_3P	G_1P		0.75	0.65	1.63	1	1½	3g	V		½	1½		4
108	PUHC 6	P_2	Sd_4P	G_1P		1.65	1.15	3.20	1	3	6g	W		½	1½		6
109¹	PUHC 7	P_2	Sd_4P	G_1P		1.45	1.15	3.20	1	3.2g	5.8g	W	5	½	1½		6
110-1	465-472	P_2	Sd_4P	G_1P		1.01	0.86	2.30	1	2	4g	V		½	1½		6
112.	475-476	P_2	Sd_4P	G_1P		1.01	0.86	2.30	1	2	4g	V		½	1½		6
113	477-480	P_2	Sd_4P	G_1P		1.01	0.86	2.30	1	2	4g	V		½	1½		6
114	481-482	P_2	Sd_4P	G_1P		1.01	0.86	2.30	1	2	4g	V		½	1½		6
141	PUHC 10	P_2	Sd_4P	G_1P		1.65	1.15	3.20	1	3	6g	W		½	1½		6
142	PUHC 8	P_2	Sd_4P	G_1P		1.65	1.15	3.20	1	3	6g	W		½	1½		6
143	PUHC 9	P_2	Sd_4P	G_1P		1.65	1.15	3.20	1	3	6g	W		½	1½		6
144	PUHC12	P_2	Sd_4P	G_1P		1.65	1.15	3.20	1	3	6g	W		½	1½		6

† W indicates that the aggregate was proportioned by weight; V by volume.

* The letter "g" after a proportion indicates that the aggregate was graded.

¹ Sand was proportioned 1.3 parts 0-20 mesh, 0.6 part 20-10 mesh, and 1.3 parts 10-¼ in mesh.

TABLE NO. 4

EFFECT OF AGE ON THE PERMEABILITY OF CONCRETE

Materials—Universal Portland Cement (P.), Janesville Sand (Sd.P.), and Janesville Gravel (Gl.P.).
All specimens were 6" thick except 164-167, which were 12" thick.
All concrete was machine mixed by a No 0 Smith mixer.
Specimens were cured in the molds for 2 days, then filled with water and sprinkled twice a day until the first tests were made; thereafter between testing periods they were allowed to stand in the permeability room filled with water. The inside surfaces of the specimens were cleaned before each test.

Batch No	Spec. No.	Mix by Vol	% Water		Age-days	Time of Mixing		Ave Humidity for 30 hr	Water Press lb/in²	Ave Rate of Leakage in Gal per Sq Ft per Hr for the Interval in Hr.			Remarks
			Nominal	+Moisture		Dry	Wet			0-50	20-50	40-50	
10	108-111	1:2:4	9.4		15	½	2½	40	22.6	.00036	.00029	.00029	
	108-111				35			30	230	00007	.00006	.00005	
	108-111				66			35	231	.00009	00008	.00008	
10	108-111	1:2:4	9 4		18			30	11.6[3]	.00013	.00015	.00015	
	108-111				39			35	13.4[3]	.00004	.00003	.00004	
	108-111				69			45	13.0	.00007			Interval 0-27 hr
11	112-115	1 2 4	9.4		15	¼	½	40	22.5	00057	.00047	.00041	
	112-115				35			30	22.6	00009	.00007	.00006	
	113-114				66			35.	23.0	00010	.00010	00010	
11	112-115	1:2:4	9.4		18			30	11.7[3]	00018	.00019	.00019	
	112-115				39			35	13.2[3]	.00003	.00003	.00005	
	113-114				69			45	12.9	.00002			Interval 0-27 hr
12	116-119	1:2:4	9.4		18	½	8½	25	21.0	.00008	.00006	.00006	
	116-119				36			35	22.3	.00003	.00003	.00003	
	116-119				63			60	222	.00001	.00001	.00001	
26	160-163	1:2:4	9 4	10.5	15	½	1½	60	23.3	.00059	.00039	.00036	
	160-163				28			65	22.5[1]	.00015	.00011	.00009	
	160-163				63			85	22.1[1]	.00012	.00006	.00005	
	160-163				196			60	42.0	.00003	.00003	.00002	
27	164-167	1:2:4	9 4	10.5	15	½	1½	60	40.9	.00065	.00048	.00040	
	164-167				29			60	40.8[2]	.00017	.00011	.00010	
	164-167				63			85	41.6[2]	00010	.00006	.00005	
	164-167				183			75	42.0	.00009	00008	.00007	
51	260-263	1:2:4	10.9	11.0	14	½	1½	85	21.7	.00071	.00047	.00041	260,262,263-M, 261-L
	260-263				28			90	22 1	.00030	.00021	.00020	
44	232-235	1:2:4	7.9	8.3	14	½	1½	80	22.3	.00023	.00011	.00009	
	232-235				28			80	22.2	.00015	.00007	.00007	

[1] Specimens were run at 10 lb between the 28 day and 63 day tests

[2] Specimens were run at 20 lb. after being run at 40 lb when 15 and 29 days old

[3] Specimens were run at 5 lb after being run at 10 lb when 18 days old; they were also run at 40 lb. after being run at 10 lb when 39 days old.

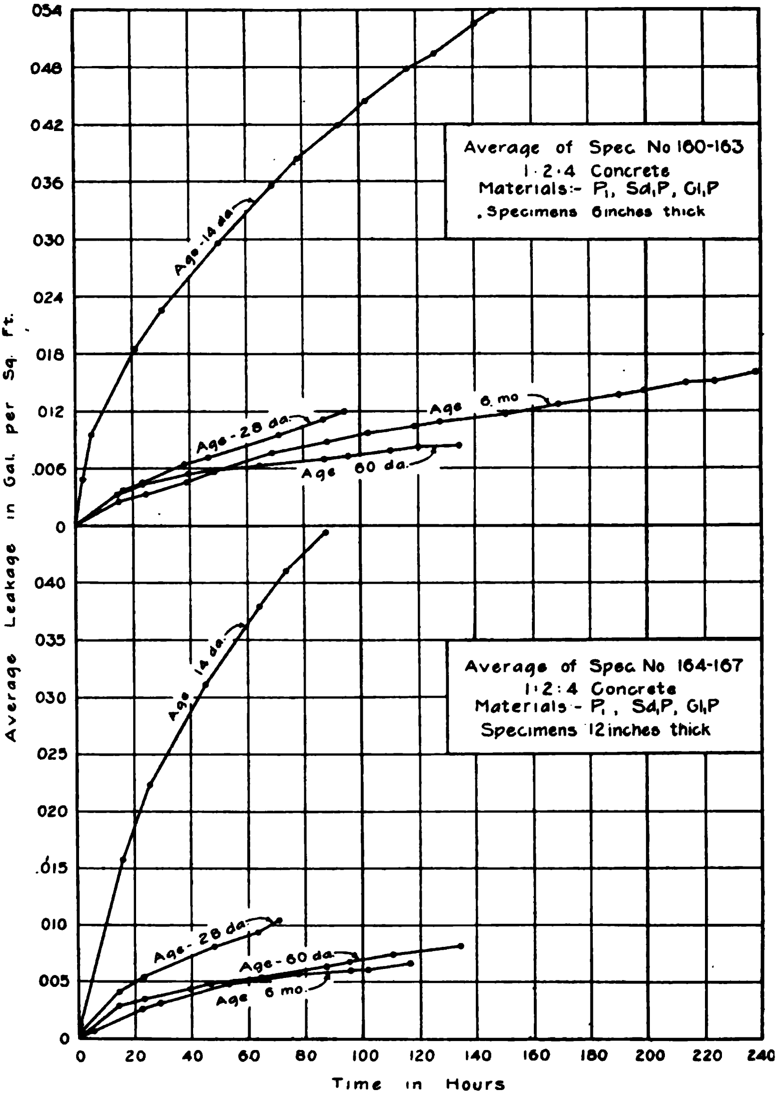


Fig. 13.— Effect of Age on the Permeability of Gravel Concrete

mens. Tests indicate that the rate of flow for the 20 to 50 hour period on a specimen which has been previously subjected to water pressure is about the same as the rate for a similar specimen tested for the first time. It therefore appears from the results in the table that the permeability of so-called impervious concrete is unaffected by age after being properly cured for one month.

Effect of Thickness on Permeability of Concrete. Although the evidence presented is by no means conclusive, the results recorded in Table 5 seem to show that the rate of flow for specimens having no visible leakage is independent of the thickness. It is barely possible, however, that the pores in the top surfaces of the thin specimens were sufficiently compressed by the bending of the core under pressure to reduce the rate of flow.

TABLE NO. 5
EFFECT OF THICKNESS ON THE PERMEABILITY OF CONCRETE

Materials.- Universal Portland cement (P$_1$), Janesville sand (Sd$_1$P), and Janesville gravel (Gl$_1$P), in all specimens except 180-195 and 220-223, in which Waukesha sand (Sd$_2$P) and Waukesha gravel (Gl$_2$P) were used
All concrete was machine mixed ½ min dry and 1½ min wet except as noted
Specimens were cured in the molds for 2 days, then filled with water and sprinkled twice a day until tested
Age at test was 1 mo

Batch No	Spec. No	Mix by Vol	% Water		Compressive Strength-lb/in²	Ave. Humidity for 50 hr.	Water Press lb/in²	Thickness-in.	Ave. Rate of Leakage in Gal per Sq Ft per Hr for the Interval in Hr			Remarks
			Nominal	•Moisture					0-50	20-50	40-50	
16	132-135	1·2·4	93		2105	50	21.8	4	000070	.000050	.000060	
17	136-139	1·2·4	93			50	21.7	8	.000136	.000103	.000110	
18	140-143	1·2 4	94			65	20.0	18	No	leakage		Tested at 40 lb first
16	132-135	1 2 4	93		2105	60	40.9	4	.000100	.000070	.000070	Tested at 20 lb first
17	136-139	1·2 4	93			60	40.8	8	.000158	.000110	.000090	. . . . .
18	140-143	1 2·4	94			55	41.2	18	.000120	.000130	.000070	
8	100-103	1 1½ 3	96	107		35	42.6	4	.000017	.000013	.000019	Mixed dry ½ min, wet 4½
9	104-107	1·1½ 3	90	102		35	42.6	8	.000042	.000030	.000030	. . . . .
15	128-131	1 1½ 3	84	87	3345	60	43.2	12			.000033	Cylinders 60 da. old
46	240-243	1 1.92 3.91	83	84	2365	85	22.3	4	.000110	.000048	.000040	
45	236-239	1 1.92 3.91	83	84		85	22.1	18	.000140	.000070	.000060	
31	180-183	1 2 4	87	96	1620	85	22.6	4	.000520	.000340	.000330	180,181-L, 182,183-D.
32	184-187	1·2·4	87	96		85	22.7	8	000370	.000200	.000170	
33	188-191	1 1½ 3	78	89	2330	85	42.6	4	.000095	.000055	.000056	
34	192-195	1 1½·3	78	89		85	42.7	8	.000067	.000036	.000042	
41	220-223	1·1½ 3	87	100		80	42.0	12	.000104	.000047	.000035	

Effect of Proportion of Cement on Permeability. From the results in Table 6, it will be observed that for proportions in which the ratio, by weight, of cement to aggregate exceeded 0.11 there was no visible indication of dampness under 40 lbs. per sq. in. pressure. It should be noted, however, that batch 57, the 1:9 mix, was made from graded aggregate and that the curing conditions for a section of concrete only 6 in. thick were much better than would ordinarily obtain in the field. An examination of Fig. 14 shows that for these materials and this procedure in mixing and curing, a proportionate increase in water-tightness is not secured by raising the weight ratio of cement to aggregate above 0.15.

Effect of Grading the Aggregate on Permeability. One of the variables most studied in making good concrete is the effect of grading the sand and gravel into different sizes and recombining these sizes in such a way that the maximum density may be obtained. In the majority of the tests reported in this paper, the gravel was screened into three sizes and recombined to form an approximately straight line mechanical analysis curve. The sizes were, however, kept separate until required for a given batch of concrete. This is essential since it is impossible to maintain a prescribed distribution of sizes in a storage pile.

TABLE NO 6

EFFECT OF PROPORTION OF CEMENT ON THE PERMEABILITY OF CONCRETE

Materials - Universal Portland Cement (P_2 in batches marked †, P_1 in all others), Janesville Sand (Sd_1P in all but 372 393 in which $Sd_{11}P$ was used), Janesville Gravel ($G1_1P$).
All specimens were 6" thick except 136-139 and 264-267 which were 8" thick
All concrete was machine mixed ¼ min dry and 1½ min. wet, except that in 372 373 and 144-145 which was well mixed on a metal tray
Specimens were cured in the molds 2 days then filled with water and sprinkled twice a day till tested.
Age at test was 1 mo

Batch No.	Spec. No	Mix		% Cement by wt	% Water		Compressive Strength-lb/in²	Density	Ave. Humidity for 50 hr	Water Press lb/in²	Ave. Rate of Leakage in Gal per Sq Ft per Hr for the Interval in Hr:			Remarks
		By Vol.	By Wt.		Nominal	+Moisture					0-50	20-50	40-50	
52	264-267	1 3·6	1·337·66	10.0	84				85	420[5]	.000452	.000340	.000320	264, 265, 266, 267-D
17	136-139	1 2 4	1 222 445	15.0	93		2105	.784	50	40.8	.000158	.000110	.000090	
19	144-145		1 2¼ 4¾	14.3	87			.786	70	415[2]	.000097	.000077	.000062	
24	154 155.		1·1⅞·3⅞	20.2	87	97		.784	80	41.7[4]	.000056	.000039	.000020	
14	124-127[1]	1 1½ 3	1 165·327	20.4	84	96	2990	.768	60	431			.000017	
57	284-287		1 3 6g	11.1	81		1505	.813	75	41.2	.000286	.000227	.000210	
77	364-367	1·1½·3g	1·162·307	21.3	80	89	2935	.792	40	42.7	.000080	.000045	.000035	
79	372-373		1:1	1018	[3]		3800		50	426	.000056	.000043	.000041	Hand mixed by hoe

[1] Specimens were run at 20 lb. for 110 hr when 28 days old.
[2] Curves showed negative leakage before 40 hr. Error was probably in blank correction
[3] Amount of water was not determined but enough was used to make a plastic mix
[4] Specimen No 154 was previously run at the same pressure
[5] Specimens were previously run at the same pressure

In Table 7 are presented the results of tests on fifteen mixes, in eight of which a portion of the aggregate was graded. The mechanical analysis curves including cement are given for these mixes in Figs. 1 and 2. For purposes of comparison Fuller's theoretical curve is also drawn on the diagrams.* Batches 19, 20, 23, 24 and 39 were proportioned by volumetric analysis; the proportions for batches 17, 52 and 77 were arbitrarily selected. None of these concretes gave visible evidence of leakage except specimens 264-267 of 1:3:6 concrete, but there is a considerable difference in the rate of flow into these dry specimens.

If mixes containing approximately the same proportion of cement, by weight, are compared it will be found that batches 23, 19 and 95 were the most impervious of the 1:5, 1:7 and 1:9 mixes, respectively. The corresponding mechanical analyses curves are 12, 6 and 5, respectively. It will be observed from the mechanical analyses curves that most of the mixes have a higher proportion of fine particles than demanded by Fuller's theoretical curve. This condition in most cases was due to the use of a large percentage of cement with a sand containing a considerable proportion of fine grains. Only a few trials were made with graded sands because of the difficulty of securing such material in practice. The results obtained with the 1:9 artificially-graded sand mixes were, however, very satisfactory.

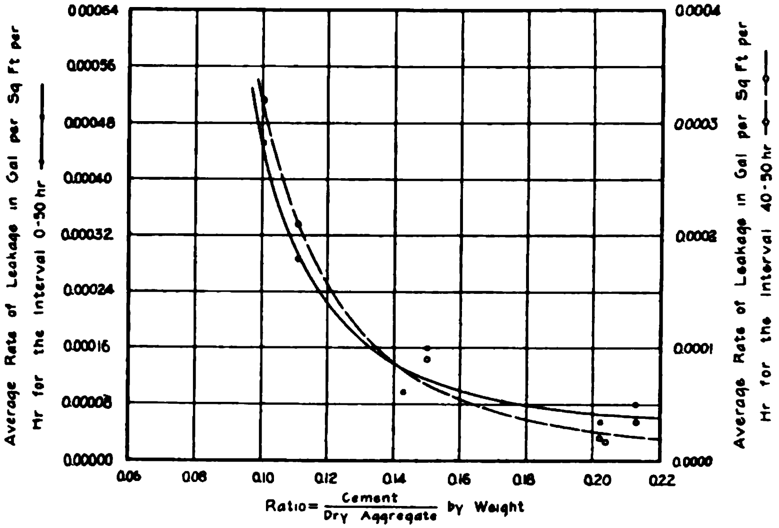


Fig 14.—Effect of the Proportion of Cement on the Permeability of Gravel Concrete*

An inspection of the mechanical analyses curves in Figs. 1 and 2 shows that the maximum size of particles in any of these mixes was about 1¼ in., and that the percentage, by weight, of particles passing a ¼-in. opening varied from 39 to 51. An analysis of the leakage data in Table 7 indicates that in the majority

---

*For the method of drawing this curve see Taylor and Thompson's *Concrete, Plain and Reinforced,* p. 202; also *Trans. A. S. C. E.,* vol. 59, p. 67, 1907.

of the more impervious mixes the percentage of this fine material was between 40 and 46.

In general, it will be observed that the flows in Table 7 decreased as the densities increased. Figure 15 shows that either the ratio of the volume of the cement particles to the volume of air voids in a unit volume of concrete or the ratio of the volume of cement particles to volume of the air plus water voids furnishes an index of imperviousness. Of the two the former seems to be a better index than the latter. A comparison of Figs. 15 and 16 shows that permeability is influenced much more than strength by a change either in the proportion of cement or in density.

TABLE NO. 7
EFFECT OF GRADING THE AGGREGATE ON THE PERMEABILITY OF CONCRETE

Aggregate:– Janesville sand ($Sd_{12}P$ in specimens numbered above 364, Sd_1P in all others.) and gravel (Gl_1P). For gradations of aggregate see Table 3 and Fig 1, 2, 3, and 4.

Specimens 144–155 were hand mixed 21 turns; all others were mixed ½ min. dry and 1½ min. wet in a No. 0 Smith mixer.

Specimens were cured in the molds for 2 days, then filled with water and sprinkled twice a day till tested.

Age of specimens at test was 1 mo. except as noted.

Batch No.	Spec. No.	Mix		Mech. Analysis Curve No.	% Water		Compressive Strength-lb/in²	Density	Ave. Humidity for 50 hr.	Water Press. lb/in²	Ave. Rate of Leakage in Gal per Sq. Ft. per Hr. for the Interval in Hr.			Remarks
		By Vol.	By Wt.		Nominal	+Moisture					0-50	20-50	40-50	
57	284-287	1:3:6	1:3:6g	3	8.1		1505	.813	75	41.2	.000287	.000227	.000210	
73	348-351		1:3.2:5.8g	4	8.2	9.0	1620	.807	50	41.9	.000490	.000280	.000230	
95	434-437		1:3.2g:5.8g	5	7.1	8.4	1550	.812	35	43.0	.000266	.000170	.000135	
52	264-267		1:3.37:6.6	14	8.4		1340		85	[4]42.0	.000452	.000340	.000320	264,5,6,7—D
48	248-251[1]		1:2.44:4.56g	9	8.0		1980		85	[2]42.4	.000110			Interval, 0-30 hr.
49	252-255[1]		1:2.12:4.88g	10	8.0		1960		90	[2]42.3	.000530			Interval, 0-18½ h
74	352-355[1]		1:2.48:4.52g	11	7.4	8.1	2210	.812	50	[2]42.4	.000112[3]	.000070		
19	144-145	1:2:4	1:2⅛:4⅜	6	8.7			.786	70	[2]41.5	.000097	.000077	.000062	
20	146-147		1:1⅛:5⅛	7	8.7			.787	70	[2]41.5	.000136	.000113	.000110	
17	136-139[1]		1:2.22:4.45	1	9.3		2105	.784	60	[2]40.8	.000158	.000110	.000090	
22	150-151		1:0.72:4.28g	8	8.7		2945	.786	60	41.4	.000086	.000054	.000042	
23	152-153		1:1¼:3¾	12	8.7			.793	60	41.4	.000046	.000020	.000012	
24	154-155		1:1⅛:3⅞	13	8.7	9.7		.784	80	41.7	.000056	.000039	.000020	
39	212-215[1]		1:1¼:3¾	12	9.1	9.7	3020	.785	90	41.7	.000135	.000073	.000057	
77	364-367	1:1½:3g	1:1.62:3.07g	2	8.0	8.9	2935	.792	40	42.7	.000080	.000045	.000035	

[1] Specimens 8 in. thick: all others, 6 in.

[2] Specimens were run at 20 lb. first; age was 33 days when started at 40 lb.

[3] Intervals were 0-38½ and 20-38½ respectively.

[4] Specimens were run at 5, 10, 20, and 30 lb; age was 35 days when started at 40 lb.

Effect of Time of Mixing on Permeability. The effects of the length of time of mixing are shown in Table 8. With a mixing period between three-fourths and five minutes, the flow through a 1:1½:3 mix appears to be independent of the total time of mixing, of the time at which the water is admitted, and of the moisture content in the sand.

There is a marked difference, however, in the behavior of lean mixes under like conditions. The results for the 1:9 mixes, in which some dry mixing was done, show that the average leakages for the two-minute period are less and the strengths greater than for either the three-quarter or five-minute mixing periods. In the wet-sand batches the superior imperviousness of those mixed two minutes over those mixed three-quarters of a minute is more pronounced than in the dry-sand batches. It will also be noted that the uniformity of the results is greater for the dry-sand batches than for those made of wet sand. This is especially true for the batches mixed three-quarters of a minute. The effect of time of mixing on 1:9 batches made from both dry and wet sands is well illustrated in Fig. 17.

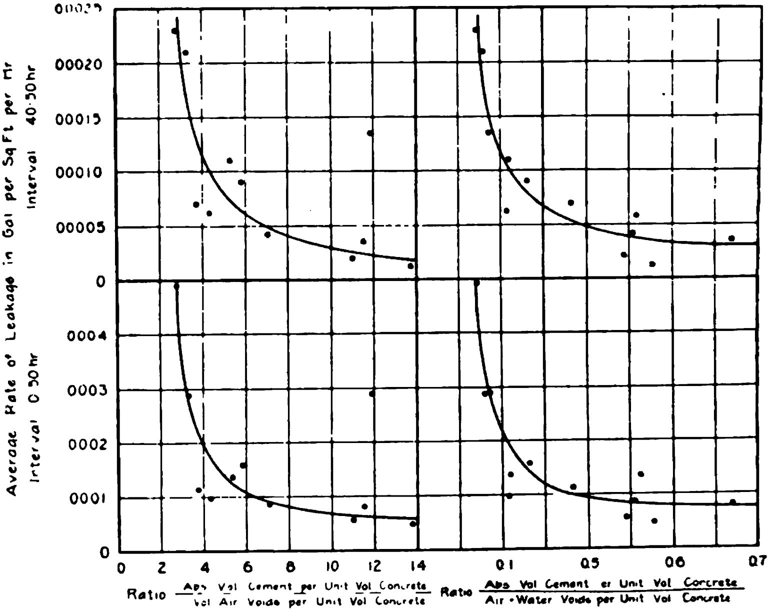


Fig 15 — Curves Showing the Relation between the Permeability and the Ratio of the Volume of Cement to the Volume of Voids in Gravel Concrete

Putting the water into the mixes before the dry materials considerably impaired the strength and imperviousness of all 1:9 batches. The injury was greatest in the three-quarter minute mix.

Effect of Consistency on Permeability. Four consistencies—dry, medium, wet and soupy—were tried on 1:1½:3 and 1:2:4 mixes. Medium and wet consistencies were also tried on 1:9 mixes. The results of these tests are given in Table 9. In placing the dry mixes, considerable ramming was done in order to secure dense concrete. Nevertheless, in the 1:1½:3 dry batch the concrete was so porous that a constant pressure could not be maintained on the specimens. The results in the table show that it is better to use too much water rather than too little, but they also indicate that a medium mixture which will barely flow is the most efficient, especially in the case of a lean mix. Increasing the percentage of water above that required for a medium consistency results in a decrease in density and a higher degree of permeability. That only a small excess of water beyond the percentage required for a medium consistency will seriously diminish the imperviousness of

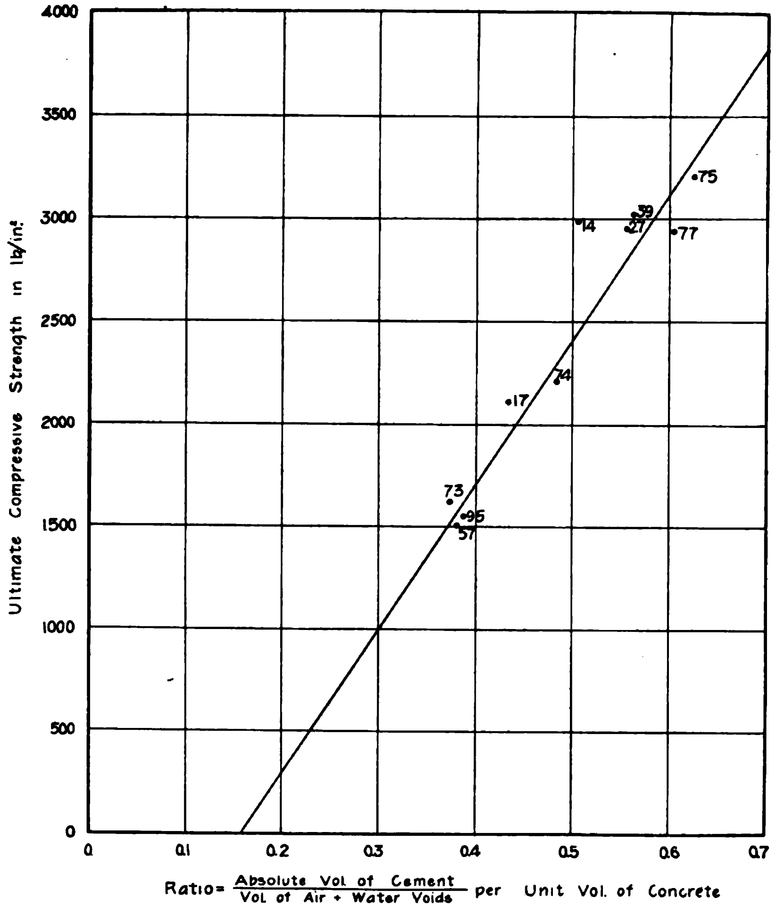


Fig 16 – Relation between the Compressive Strength and the Ratio of the Volume of Cement to the Volume of Voids in Gravel Concrete

a well-graded 1:9 mix, is clearly shown by the results in Tables 9 and 13.

A Comparison of the Effects of Fineness of Cement, Consistency, Gradation of Aggregate, and Time of Dry Mixing on the Permeability of 1:9 Concrete. From the evidence presented in Table 10, it appears that the imperviousness and strength of a lean mix can be increased somewhat by grading the aggregate or by grinding the cement to a greater degree of fineness than ordinarily practiced. Under good curing conditions, however, the advantages secured by either method may be greatly overbalanced by making the mix too wet or by placing water in the mixer ahead of the cement and aggregate.

TABLE NO. 8

EFFECT OF TIME OF MIXING ON THE PERMEABILITY OF CONCRETE

Materials:- Universal Portland cement (P_1 in all specimens numbered below 287, P_2 in all others). Janesville sand (Sd_1P in all specimens numbered below 347, Sd_2P in all others). Janesville gravel (Gl_1P).
All concrete was machine mixed. In all wet sand mixes dry sand was put into the machine and thoroughly mixed with about 7% of water before the cement and gravel were added. In batches 92-94 and 98-100 the water was admitted to the mixer first.
All specimens were 6 in. thick.
Specimens were cured in the molds for 2 days, then filled with water and sprinkled twice a day until tested.
Age at test was 1 mo. except specimens 108-114 which were 2 mo. old.

Batch No.	Spec. No.	Mix By Vol.	Mix By Wt.	% Water Nominal	% Water +Moisture	Time of Mixing Dry	Time of Mixing Wet	Condition of Sand	Compressive Strength lb/in²	Ave. Humidity for 50 hr	Water Press. lb/in²	Ave. Rate of Leakage in Gal. per Sq. Ft. per Hr. for the Interval in Hr. 0-50	20-50	40-50	Variation in % 40-50	Remarks
82	384-387	1:1½:3g		8.0	9.2	¼	½	*	3030	45	42.7	.000138	.000056	.000051	40	
85	397-399	1:1½:3g		8.0	9.1	¼	½	wet	3315	35	42.5	.000036	.000038	.000050	50	
77	364-367	1:1½:3g		8.0	8.9	½	1½	*	2935	40	42.7	.000080	.000045	.000035	50	
84	392-395	1:1½:3g		8.0	8.9	½	1½	wet	3475	40	42.3	.000063	.000046	.000035	60	
81	380-383	1:1½:3g		8.0	9.2	½	4½	*	2905	45	42.4	.000098	.000038	.000028	180	
83	388-391	1:1½:3g		8.0	8.9	½	4½	wet	3245	40	42.1	.000072	.000057	.000043	120	No. 390 not tested
11	113-114	1:2:4		9.4		¼	½	*		60	41.9[1]	.000606[2]		.000356[2]	60	
10	108-111	1:2:4		9.4		½	2½	*		60	41.6[1]	.000428[2]		.000221[2]	30	
56	280-283		1:3:6g	8.2		¼	½	*	1025	75	42.1	.001140	.000810	.000750	60	
66	320-323		1:3:6g	8.2		¼	½	wet	1025	45	42.5	.001860	.001600	.001500	120	320-L, 321,323-M
57	284-287		1:3:6g	8.1		½	1½	*	1505	75	41.2	.000287	.000227	.000210	20	
65	316-319		1:3:6g	8.2		½	1½	wet	1550	50	42.9	.000294	.000167	.000120	80	
55	276-279		1:3:6g	8.2		½	4½	*	1300	75	42.2	.000300	.000180	.000170	20	Only 2 comp. cyl.
68	328-331		1:3:6g	8.2		½	4½	wet	1355	70	42.1	.000320	.000180	.000170	50	All discolored
72	344-347		1:3:6g	8.2	8.4	Hand-9 turns			990	50	42.9	.000620	.000340	.000250	80	All discolored
98	438-441	1:1½:3g		8.0	9.5	0	¾	*	3110	40	43.1	.000089	.000052	.000046	80	
99	442-445	1:1½:3g		8.0	9.5	0	2	*	3015	40	43.1	.000093	.000045	.000041	40	
100	446-449	1:1½:3g		8.0	8.3	0	5	*	3155	40	42.7	.000067	.000045	.000040	60	
92	422-425		1:3:6g	8.2	8.3	0	¾	*	885	25	40.8	.005800	.005530	.005600	270	422-L, 423-D
93	426-429		1:3:6g	8.2	9.5	0	2	*	900	25	39.9	.001090	.000630	.000750	130	429-M
94	430-433		1:3:6g	8.2	9.5	0	5	*	1000	25	41.0	.001100	.000950	.001200	230	430-M; 432-D

[1] Specimens were tested at lower pressures when 15 and 28 days old * Air-dried
[2] Intervals were 0-39½ hr. and 30-39½ hr. respectively. Specimens 108-111 were 60 days old when tested.
Note - Gravel in batches 93 and 94 contained 1.83% moisture; gravel in batch 92 had only 0.4% moisture. The same percentage of water was added in mixing each of these batches.

Effect of Curing Conditions on Permeability. That no single operation in making concrete has a more important effect upon its water-tightness than the procedure in curing, will be appreciated after an examination of the data in Table 11. By early removal of

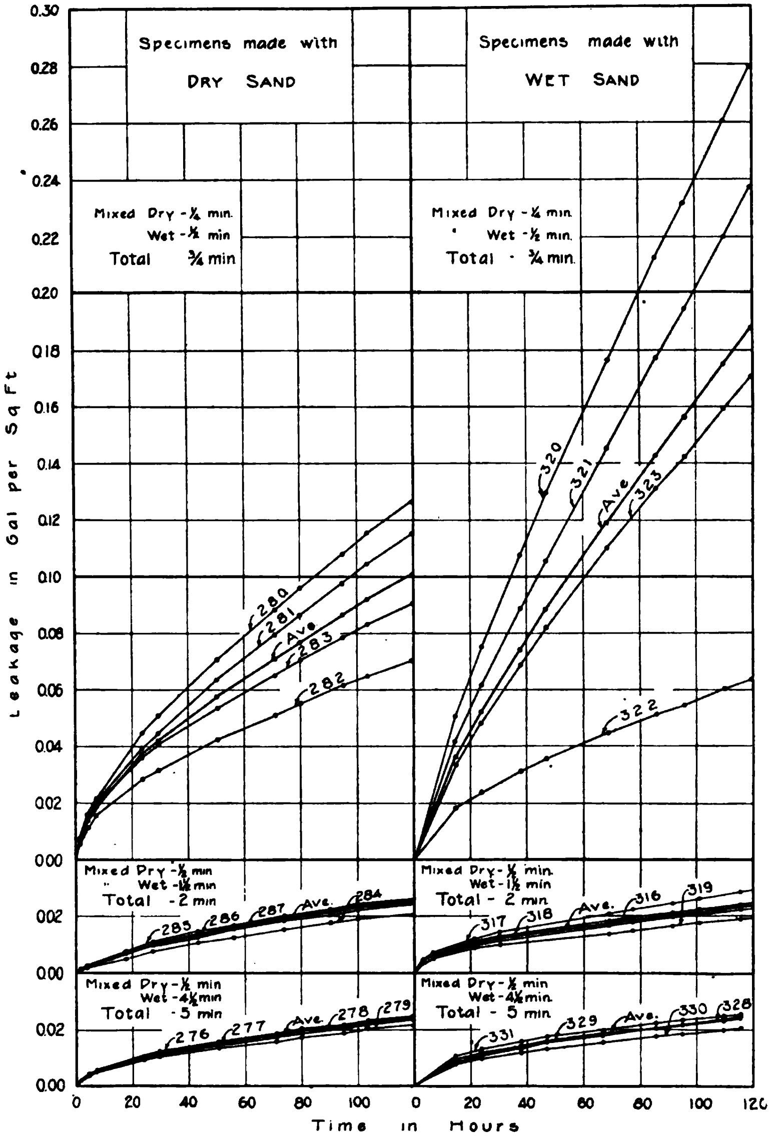


Fig. 17—Effect of Time of Mixing on the Permeability of 1·9 Gravel Concrete Made from Wet and Dry Sand

molds followed by drying in air at room temperature, the flow through a 1:9 mixture was increased about 140 times, see batches 57 and 69. Curing for seven days in the molds was not so efficient for a 1:9 mix as to cure for two days in the molds and sprinkle for five days. The latter method, however, was insufficient for the production of a watertight mix, see specimens 405-407 and 410-411. Even after sprinkling for three weeks, a period of six days in an oven at a temperature between 115 and 185 deg. Fahr. was sufficient to make specimens 408 and 409 leak about sixty times as fast as specimens 406 and 407 of the same batch which were sprinkled until tested. Sprinkling for one month, followed by an equal subsequent period of curing in normal air at room temperature, did not adversely affect the imperviousness of specimens 436 and 437.

TABLE NO. 9

EFFECT OF CONSISTENCY ON THE PERMEABILITY OF CONCRETE

Materials — Universal Portland cement (P$_1$ in specimens numbered below 263. P$_2$ in all others). Janesville sand (Sd$_4$P in specimens numbered below 319 except as noted. Sd$_{12}$P in all others). Janesville gravel (Gl$_1$P)
All concrete was machine mixed ½ min dry and 1½ min wet
All specimens were 6 in thick except as noted.
Specimens were cured in the molds for 2 days, then filled with water and sprinkled twice a day until tested
Age at test was 1 mo

Batch No	Spec No	Mix		% Water		Compressive Strength lb/in²	Density	Ave Humidity for 50 hr	Water Pressure lb/in²	Ave Rate of Leakage in Gal. per Sq Ft per Hr for the Interval in Hr.			Remarks
		By Vol	By Wt	Nominal	Moisture[4]					0-50	20-50	40-50	
75	356-359	1 1½ 3g		6.0	7.5	3205		45		Excessive Leakage[5]			
77	364-367	1 1½ 3g		80	89	2935	.792	40	427	.000080	.000045	.000035	
78	368-371	1 1½ 3g		99	108	1560	.779[4]	40	426	.000060	.000050	.000035	
76	360-363	1 1½ 3g		120	135	1325	.745[4]	45	423	.000260	.000160	.000120	
50	256-259	1·2 4		64	64	2200	.796[4]	90	228	.000500[3]	.000300	.000300	
44	232-235	1·2 4		79	83		.797[4]	80	222	.000150	.000073	.000067	
26	160-163	1·2 4		94	105		.776[4]	65	225[2]	.000150	.000110	.000095	
51	260-263	1 2·4		109	110	995	.756[4]	90	221[2]	.000300	.000210	.000200	
23	152-153		1·1¼ 3¼	87			.793	60	414	.000048	.000020	.000012	Hand mixed 21 turns
39	212-215		1·1¼ 3¼	91	97	3020	.785	90	417	.000135	.000073	.000057	Spec 8 in thick
65	316-319[1]		1·3·6g	82		1550	.804[4]	50	429	.000294	.000167	.000120	
64	312-315[1]		1·3·6g	100		900	.774	50	421	.010300	.009100	.008400	312, 313, 314–L; 315–M
95	434-437		1 32g 58g	71	84	1550	.812	35	430	.000280	.000170	.000135	
86	400-403		1·3.2g 58g	82	94	1120		35	418	.001680	.001480	.001700	400–M; 401, 402, 403–D

[1] Sand was wetted with 7% of water before cement and gravel were put in mixer (See also Table 8)
[2] Specimens had been run at same pressure when 14 days old
[3] Specimen No 259 leaked 0.4 gal in 3 min, test on this specimen was discontinued Results are averages for three specimens
[4] Density was obtained from same mix of Sd$_{14}$P and Gl$_1$P graded to conform to the mechanical analyses of the original materials
[5] Leakage took place under a head of 5 feet

Mixtures of 1:2:4g proportions withstood the bad effects of premature drying out much better than the 1:9 mixes, although the influences are plainly seen in the results.

As expected, the 1:1½:3 mixes were affected but little by dry curing. The greatest effect was obtained from tests of specimens 376 to 379 cured one day in molds and twenty-six days in air. Although they showed no visible evidences of leakage, the rate of flow was about twenty-five times that of specimens 364-367 which were sprinkled for one month.

From Table 12 a comparison can be made between the percentages of weight lost in curing and the leakages. In general, it will be observed that the leakage increases with the per cent loss in weight.

Figure 18 shows the effects of certain curing conditions on both 1:1½:3 and 1:9 mixes.

Results of the compressive strength tests indicate that premature drying out somewhat adversely affected the strength of 1:9 mixes but did not injure the strength of the 1:1½:3 mixes.

TABLE NO. 10

A COMPARISON OF THE EFFECTS OF FINENESS OF CEMENT CONSISTENCY GRADATION OF AGGREGATE AND TIME OF DRY MIXING ON THE PERMEABILITY OF 1:9 CONCRETE

Materials:—Universal Portland cement (P_1 in specimens numbered below 295, P_2 in all others); Janesville sand (Sd_1P in specimens numbered below 315, Sd_2P in all others), Janesville gravel (Gl_1P).
All concrete was machine mixed.
All specimens were 6 in. thick.
Specimens were cured 2 days in molds, then filled with water and sprinkled twice a day till tested.
Age at test was 1 mo.

Batch No.	Spec. No.	Mix by Wt.	% Water		Time of Mixing		Compressive Strength lb/in²	% Cement Held on No. 200 Sieve	Ave. Humidity for 50 hr.	Water Press. lb/in²	Ave. Rate of Leakage in Gal per Sq Ft per Hr. for the Interval in Hr.				Remarks
			Nominal	*Moisture	Dry	Wet					0-50	20-50	40-50	Variation in % 40-50	
59	292-295	1·3·6g	8.6		½	1½	1990	5.5	65	42.4	.00020	.00016	.00014	120	
60	296-299	1·3·6g	8.6		½	1½	1485	15.2	70	40.2	.00077	.00064	.00058	80	
57	284-287	1·3·6g	8.1		½	1½	1505	20.3	75	41.2	.00028	.00023	.00021	20	
64	312-315	1·3·6g	10.0		½	1½	900	21.8	50	42.1	.01030	.00910	.00840	100	312,3,4-L; 315-M
86	400-403	1·3.2g·5.8g	8.2	9.4	½	1½	1120	21.8	35	41.6	.00168	.00148	.00170	100	400-M, 401,2,3-D
95	434-437	1·3.2g·5.8g	7.1	8.4	½	1½	1550	21.8	35	43.0	.00029	.00017	.00014	120	
93	426-429	1·3·6g	8.2	9.5	0	2	900	21.8	25	39.9	.00109	.00063	.00075	130	429-M.

*Sand was wetted with 7% of water before cement and gravel were put into the mixer

Effect of Direction of Flow on Permeability. Inasmuch as the larger particles of stone and sand flow more rapidly toward the bottom of a wet mix than do the fine particles of sand and cement, there is a tendency for the formation of strata of stone, sand and cement. Since such formations must decrease the homogeneity of the concrete, and since many constructions must withstand water pressure applied perpendicular to the direction in which the concrete is poured, a few tests were made to compare the permeabilities of specimens in which the direction of flow was parallel to the bed upon which they were cast (the horizontal) with the

TABLE NO. 11

EFFECT OF CURING CONDITIONS ON THE PERMEABILITY OF CONCRETE

Materials—Universal Portland cement (R in specimens numbered 284-287, R_2 in all others). Janesville sand (Sd_4P in specimens numbered 284-313, $Sd_{12}P$ in those numbered 364-437, Sd_3P in all others); Janesville gravel (G_4P).
All concrete was machine mixed.
All specimens were 6 in. thick.
After removal from the molds the surfaces of all air-cured specimens were well chipped and the test-pieces placed in a hall without being filled with water. Sprinkling was done with a hose each morning and evening as indicated. Artificial drying was accomplished by placing the specimens in an oven and raising the temperature in 2 or 3 hours to about 170°F. In drying specimens 340-343 the temperature once rose to 250°F for a period of about one hour.

Batch No.	Spec. No.*	Mix		% Water		Compressive Strength lb/in²	Ave. Humidity for 30 hr.	Water Press. lb/in²	Days Cured in				Ave. Rate of Leakage in Gal per Sq Ft per Hr. for the Interval in Hr.			Remarks
		By Vol.	By Wt.	Nominal	*Moisture				Molds	Sprinkled	Air	Oven	0-50	20-50	40-50	
57	284-287		1:3:6g	8.1		1505	75	412	2	26			.000280	.000227	.000210	
69	332-335		1:3:6g	8.2		1150[2]	70	418	1		27		.031400	.028500	.028500	332, 333, 334, 335-L
70	336-339		1:3:6g	8.2		1595	50	430	1		27[2]		.000316	.000357	.000330	
87	406-407[4]		1:3:6g	8.2	9.5	1510	30	419	2	28			.000440	.000390	.000300	
87	404-405[1]		1:3:6g	8.2	9.5	1220	30	419	2	5	23		.007120	.006100	.005800	404, 405-L
88	410-411[1]		1:3:6g	8.2	9.5	1260	30	418	7[4]		23		.012200	.012200	.012400	410-L, 411-D
88	408-409		1:3:6g	8.2	9.5	1170	30	418	2	22		6	.024600	.024800	.024500	408, 409-L
71	340-343[1]		1:3:6g	8.2	8.4	1515	55	411	2	23		7	.020600[3]	.017100[3]		
71	342[1]		1:3:6g	8.2	8.4	1515	55	411	2	23		7	.013600	.011800	.010700	
95	434-435		1:3.2:5.8g	7.1	8.4	1550	35	430	2	26			.000218	.000123	.000090	
	436-437		1:3.2:5.8g	7.1	8.4	1550	35	430	2	26			.000356	.000217	.000180	
	434-435		1:3.2:5.8g	7.1	8.4		45	434			33[7]		.000286	.000133	.000070	
	436-437		1:3.2:5.8g	7.1	8.4		45	433			33		.000420	.000227	.000160	
86	400-401		1:3.2:5.8g	8.2	9.4	1120	35	418	2	27			.001510	.001400	.001330	400-M, 401-D
	400-401		1:3.2:5.8g	8.2	9.4		35	424			29[8]		.001310	.000990	.000920	400-D
	400-401		1:3.2:5.8g	8.2	9.4		45	431			33		.001260	.000777	.000800	Test age, 106 days
104	461-462		1:3.2:5.8g	7.1	8.5		55	424	6		57[5]		.004140	.003330	.003100	461, 462-L
104	463-464		1:3.2:5.8g	7.1	8.5		55	420	6		57		.009500	.007270	.006800	463, 464-L
110	465-466	1:2:4g		7.9	8.5	1530	60	415	1		28		.005440	.003760	.003660	
110	467-468	1:2:4g		7.9	8.5	1935	60	417	2	27			.000120	.000054	.000050	
111	469-470	1:2:4g		7.9	8.5	1765	60	430	4		25		.001610	.000931	.000870	
111	471-472	1:2:4g		7.9	8.5	2040	60	430	6		23		.001100	.000643	.000600	
113	477-478	1:2:4g		7.9	8.3	2570	75	431	13		15		.000373	.000202	.000165	
113	479-480	1:2:4g		7.9	8.3	2620	75	431	20		8		.000347	.000166	.000140	
114	481-482	1:2:4g		7.9	8.4	1750	70	424	2	3	24		.001360	.000940	.000775	Sprinkled after air curing
112	475-476	1:2:4g		7.9	8.3	2906	75	434	2	56		3	.000594	.000249	.000180	
77	364-367	1:1½:3g		8.0	8.9	2935	40	427	2	26			.000080	.000045	.000035	
80	376-379	1:1½:3g		8.0	9.3	3262	50	420	1		26		.001900	.001140	.000890	
89	414-415[1]	1:1½:3g		8.0	8.2	3460	30	415	2	26			.000021	.000017	.000014	
89	412[1]	1:1½:3g		8.0	8.2	3700	30	415	2	5	21		.000140	.000093	.000088	
103	458-459[1]	1:1½:3g		7.9	9.4	2810	30	429	6		22[3]		.000150	.000107	.000097	
103	460[1]	1:1½:3g		7.9	9.4	2990	30	429	6		22		.000326	.000227	.000200	
102	454-455[1]	1:1½:3g		7.9	9.4	2650	55	430	6		57[6]		.000218	.000140	.000130	
102	456-457[1]	1:1½:3g		7.9	9.4	3550	55	429	6		57		.000682	.000410	.000250	
102	455[1]	1:1½:3g		7.9	9.4		70	429			56		.000480	.000276	.000210	Test age, 126 days
91	418-419	1:1½:3g		7.9	8.0	3085	20	424	2	26			.000072	.000053	.000039	
91	420-421	1:1½:3g		7.9	8.0	3325	20	424	2	20			.000167	.000135	.000103	

[1] These specimens were mixed ½ min dry and 4½ min wet; all others were mixed ½ min dry and 1½ min wet.
[2] While being cured in air these specimens were filled with water.
[3] Results are for intervals from 0-44 and 20-44 hr respectively.
[4] The tops of these specimens were sprinkled while in the molds.
[5] These specimens were filled with water 7 da before testing after having stood in air for 16 da. They were not sprinkled at any time however.
[6] These specimens were filled with water 10 da before testing.
[7] These specimens were filled with water after the 28 da test and stood in air till the 60 da test.
[8] These specimens were full of water during the last 12 da of this period.
[9] Cylinders were removed to the hall after 4 da in the molds.

permeabilities of *PU* specimens in which the direction of flow was normal to the bed. Table 13 contains the data from the tests thus far made. Before making comparisons it should be noted that the *PUL* and *PUHC* specimens were not given so good curing conditions as the *PU* specimens; because, in spite of the wet cement sacks wrapt around the outside of the former specimens, they were not kept as uniformly moist as the latter. Also it should be noted that *PUHC* 1-5 were only 4 in. thick. However, making due allowance for discrepancies if we compare specimens *PUL* 3, *PUL* 6, *PUHC* 1-3 with *PU* 400-403, it appears that the permeabilities of the 1:9 *PUHC* and *PUL* specimens of wet consistency were considerably greater than the permeabilities of the corresponding *PU* specimens. By comparing batches 108 with 57 and 109 with 95

TABLE NO 12

EFFECT OF LOSS OF WEIGHT DUE TO CURING CONDITIONS ON THE PERMEABILITY OF CONCRETE

For information concerning the method of making and curing specimens, refer to Table 11

Batch No	Spec. No.	Mix		% Water		% Wt. Lost by Cylinders	Compressive Strength-lb/in²	Ave. Humidity for 50 hr	Water Press. lb/in²	% Wt. Lost by Perm. Spec.	Ave. Rate of Leakage in Gal per Sq. Ft. per Hr. for the Interval in Hr.			Remarks
		By Vol	By Wt	Nominal	*Moisture						0-50	20-50	40-50	
87	404		1:3·6g	8.2	9.5	1.54	1130	30	41.9	3.16	.006940	.005830	.005500	404-M
	405		1:3·6g	8.2	9.5	1.83	1310		41.9	3.39	.007300	.006370	.006100	405-M
88	411		1:3·6g	8.2	9.5	2.23	1200	30	41.8	2.00	.003800	.003000	.003000	411-D
	410		1:3·6g	8.2	9.5	2.25	1320		41.8	2.44	.020500	.021300	.021800	410-L
	408		1:3·6g	8.2	9.5	2.48	995		41.8	3.14	.017400	.017500	.017000	408-L
	409		1:3·6g	8.2	9.5	2.37	1340		41.8	3.80	.031800	.032000	.032000	409-L
110	468	1:2·4g		7.9	8.5	0.55	1980	60	41.7	-0.50	.000130	.000058	.000056	Specimens gained wt
	467	1:2·4g		7.9	8.5	0.82	1890		41.7	-0.45	.000110	.000051	.000052	" " "
	465	1:2·4g		7.9	8.5	2.84	1585		41.5	2.20	.005800	.003900	.003770	
	466	1:2·4g		7.9	8.5	2.83	1470		41.5	2.35	.005070	.003670	.003550	
111	472	1:2·4g		7.9	8.5	1.90	2030	60	43.1	1.96	.001070	.000647	.000600	
	471	1:2·4g		7.9	8.5	1.90	2050		43.1	1.98	.001130	.000640	.000600	
	470	1:2·4g		7.9	8.5	1.91	1880		43.0	2.25	.001680	.000900	.000860	
	469	1:2·4g		7.9	8.5	1.89	1650		43.0	2.38	.001540	.000963	.000880	
113	479	1:2·4g		7.9	8.3	1.36	2580	75	43.1	0.89	.000316	.000150	.000130	
	480	1:2·4g		7.9	8.3	1.08	2655		43.1	1.04	.000378	.000183	.000150	
	478	1:2·4g		7.9	8.3	1.33	2385		43.0	1.56	.000358	.000187	.000160	
	477	1:2·4g		7.9	8.3	1.60	2760		43.0	1.70	.000388	.000217	.000170	
114	482	1:2·4g		7.9	8.4	2.84	1800	70	42.4	2.59	.001250	.000897	.000770	
	481	1:2·4g		7.9	8.4	3.09	1705		42.4	2.75	.001460	.000983	.000780	
112	476	1:2·4g		7.9	8.3	1.60	2700	75	43.4	0.52	.000436	.000198	.000136	
	475	1:2·4g		7.9	8.3	1.63	3112		43.4	1.30	.000752	.000300	.000223	
89	414	1:1½:3g		7.9	8.2	-0.27	3795	30	41.5	-0.87	.000023	.000019	.000015	Specimens gained wt.
	415	1:1½:3g		7.9	8.2	-0.27	3125		41.5	-0.52	.000019	.000015	.000014	" " "
	412	1:1½:3g		7.9	8.2	1.09	3700		41.5	1.91	.000140	.000093	.000088	
91	418	1:1½:3g		7.9	8.0		3130	20	42.4		.000064	.000050	.000030	Weights not recorded probably gained wt.
	419	1:1½:3g		7.9	8.0		3040		42.4		.000078	.000057	.000048	
	420	1:1½:3g		7.9	8.0	1.67	3540		42.4	1.40	.000153	.000122	.000105	
	421	1:1½:3g		7.9	8.0	0.82	3110		42.4	1.46	.000180	.000147	.000100	
103	459	1:1½:3g		7.9	9.4	-0.14	2940	30	42.9	2.07	.000167	.000122	.000115	
	458	1:1½:3g		7.9	9.4	-0.41	2680		42.9	2.22	.000133	.000092	.000078	
	460	1:1½:3g		7.9	9.4	2.22	2990		42.9	2.55	.000326	.000227	.000200	

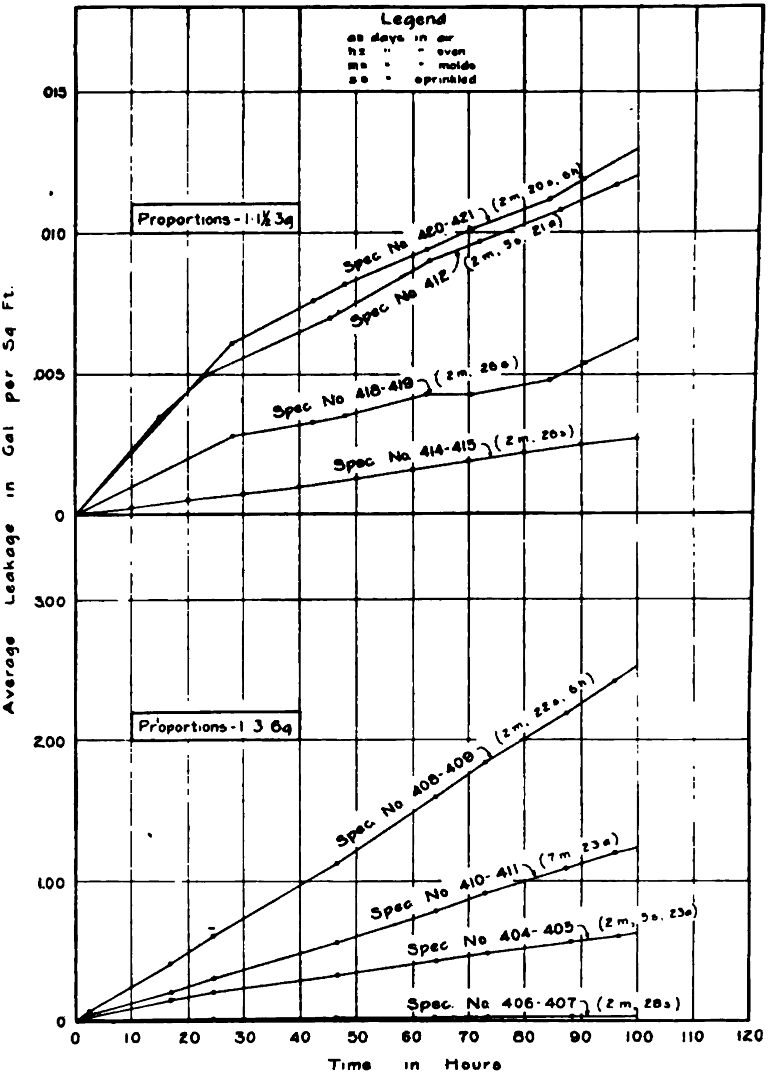


Fig. 18— Effect of Different Methods of Curing on the Permeability of Gravel Concrete

it will be seen that the difference between the rates of flow of the *PUHC* and *PU* specimens of medium consistency was not so great. The large influence of consistency upon the permeability of 1:9 concrete is well brought out by the data for *PUHC* 8, 9, 10 and 12.

For the 1:1½:3 mixes the *PUL* specimens had a greater leakage and the *PUHC* specimens a smaller rate of flow than the *PU* specimens. These mixes were all, however, of medium consistency.

TABLE NO. 13

EFFECT OF DIRECTION OF FLOW ON THE PERMEABILITY OF CONCRETE

Materials:- Universal Portland cement (P_2), Janesville sand (Sd_2P in spec. 364-367, 434-437, PUL 2-3, $Sd_{14}P$ in PUHC 6-7, Sd_1P in spec. 284-287; Sd_8P in all others), and Janesville gravel (G_4P).
All concrete was machine mixed ½ min. dry and 1½ min. wet except as noted.
All PUHC specimens from 1-5 inclusive were 4 in. thick; all other PUHC and all PU and PUL spec. were 6 in. thick. For dimensions and form of specimens see Fig. 5 and 6.
For methods of treatment previous to testing, see paragraph on curing.
All specimens were tested at 1 mo. except PUL 2 which was subjected to pressure at 8 days

Batch No	Spec No	Mix		% Water		Compressive Strength-lb/in²	Ave. Humidity for 50 hr.	Water Press lb/in²	Direction of Flow		Ave Rate of Leakage in Gal. per Sq. Ft. per Hr for the Interval in Hr			Remarks
		By Vol	By Wt	Nominal	Moisture				Parallel to Bed	Perpendicular to Bed	0-50	20-50	40-50	
96	PUL 2		1·1	15.7			30	41.3	do		.000123	.000102	.000095	
97	PUL 3[2]		1:3:6g	8.2		980	35		do		Excessive Leakage - Spec			leaked .11 gal in 1 min
105	PUL 6		1:3.2g:5.8g	7.1	8.5		35	42.2	do		.014300	.006000	.005300	Leaked badly
106	PUHC 1[3]		1:3:6g	8.1	9.8	1170	40	40	do				.186000	Spec. run 2½ min.
106	PUHC 2[3]		1:3:6g	7.2	8.8	1265	50	40	do				.023300	Spec. run 22 min.
106	PUHC 3[3]		1:3:6g	7.4	9.1	1205	50	40	do				.067800	Spec. run 10 min.
108	PUHC 6[3]		1:3:6g	7.2			55	42.5	do		.000686	.000631	.000624	3 damp spots
109	PUHC 7		1:3.2g:5.8g	7.1	7.2	1665	55	42.5	do		.000638	.000497	.000462	1 damp spot
108	PUHC 6[5]		1:3:6g	7.2			75	42.5	do		.000150	.000135	.000135	
109	PUHC 7[5]		1:3.2g:5.8g	7.1	7.2		75	42.5	do		.000166	.000150	.000150	
142	PUHC 8		1:3:6g	7.9	8.7		75	42.1	do		.002150	.001730	.001620	Leaked badly
143	PUHC 9		1:3:6g	7.2	7.9		75	42.0	do		.001430	.001280	.001200	½ of surface damp.
141	PUHC 10		1:3:6g	6.7			75	42.4	do				.029500	Porous near bottom
144	PUHC 12		1:3:6g	6.7	7.5		75	41.8	do		.000322	.000274	.000273	Moist spot 4 in in diam near bottom
57	PU 284-7		1:3:6g	8.1		1505	75	41.2		do	.000287	.000227	.000210	
95	PU 434-7		1:3.2g:5.8g	7.1	8.4	1550	35	43.0		do	.000288	.000170	.000135	
86	PU 400-3		1:3.2g:5.8g	8.2	9.4	1120	35	41.8		do	.001680	.001480	.001700	400-M; 401, 402, 403-D
101	PUL 4[1]	1:1½:3g		7.9	8.9	2990	40	42.6	do		.000210	.000177	.000160	
103	PUL 5[1]	1:1½:3g		7.9	9.4		30	42.1	do		.000136	.000120	.000110	
107	PUHC 4[2]	1:1½:3g		7.9	9.5	3415	50	42.0	do		.000021	.000019	.000019	
107	PUHC 5[2]	1:1½:3g		7.9	9.5	3095	70	44.2	do		.000023	.000018	.000023	
77	PU 364-7	1:1½:3g		8.0	8.9	2935	40	42.7		do	.000060	.000045	.000035	

[1] Specimens were mixed ½ min. dry and 4½ min. wet
[2] Specimens were mixed 0 min. dry and ¾ min. wet
[3] Sand used passed ¼ in. sieve
[4] Sand used as received.
[5] Specimens were 3 mo. old at test.
[6] Specimen was run 15 min.

The Relation Between Permeability and Compressive Strength. In Fig. 19 have been plotted the permeabilities against the strengths for the concretes of medium consistency which were cured by sprinkling. The results found in Tables 9, 11 and 12 do not appear in this diagram. If concrete which leaks less than 0.0001 gallon per square foot per hour under 40 lbs. per sq. in. pressure be considered impervious, then from Fig. 19 it appears that concretes having a compressive strength above 2,500 lbs. per sq. in. may be so considered. Since the use of a too dry consistency or improper curing conditions very seriously affect the permeability but do not markedly influence the compressive strength, the application of the above conclusion must be limited to properly cured concrete of medium consistency.

Indications That Water Flowed Through the "Dry" Specimens. Since in these tests only the quantity of water entering the specimen was measured and no quantitative measurements of the amount passing out were taken, it may appear that for specimens showing no evidences of leakage the rate of absorption rather than the permeability was determined. It must be borne in mind, however, that specimens normally cured were filled with water for about a month previous to testing, that their outsides were encased with a tight mortar shell which was swathed in wet cement sacks, and that the bottoms of the specimens rested on a cement floor which was always damp. Consequently, for specimens thus cured, it is a fair assumption that most of the absorption had taken place be-

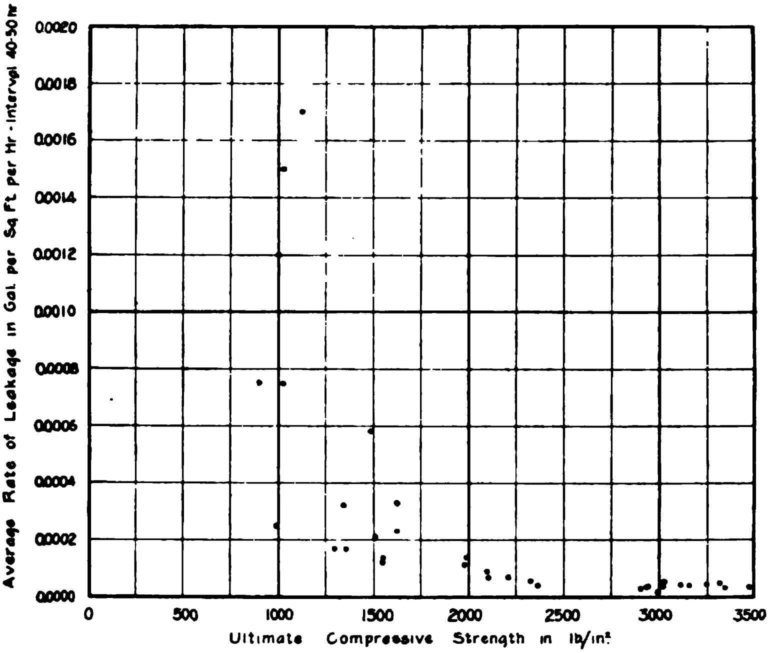


Fig 19 — Relation between the Compressive Strength and the Permeability of Well-Cured Gravel Concrete of Medium Consistency

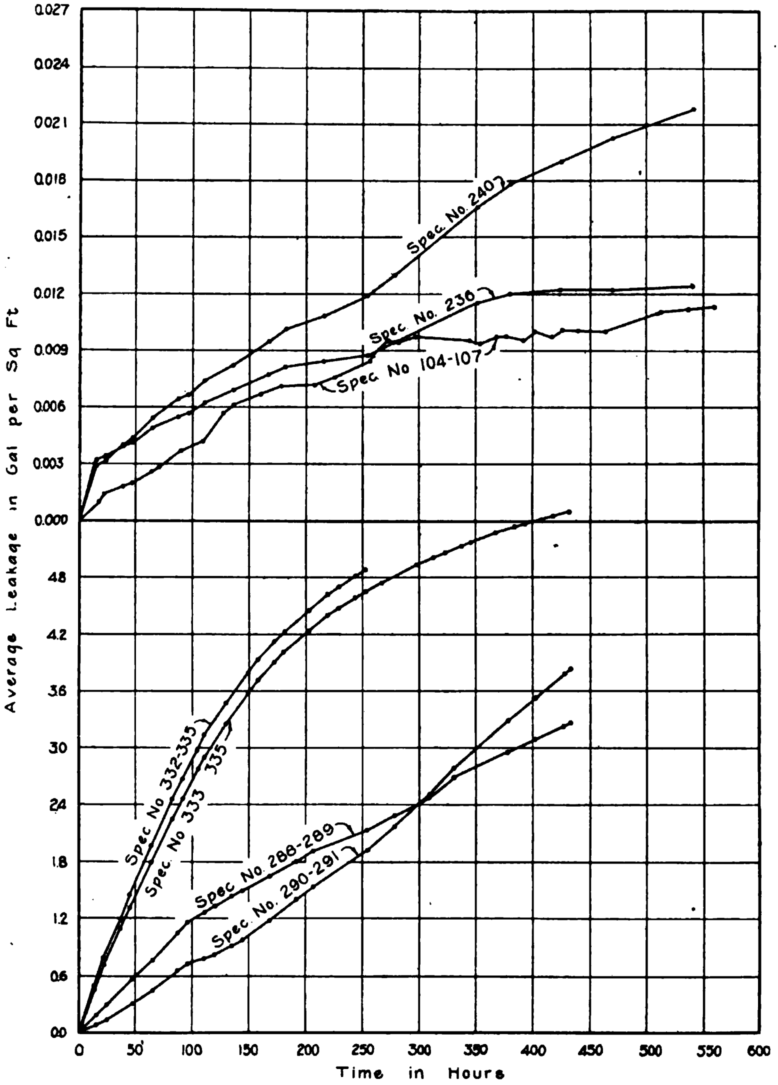


Fig 20.—Effect of Duration of Flow on the Rate of Flow of Water into Gravel Concrete

fore the permeability test began. From the shapes of the leakage-time curves it seems probable that the remaining empty pores were filled during the first ten or twenty hours of the test.

Next consider the possibility of the quantity of water entering the specimens disappearing from the bottoms due to evaporation. With a humidity of 75% the maximum observed flow into any "dry" specimen for a fifty-hour period was approximately 0.0015 gallon per square foot per hour. From experiments one drop was found to be equivalent to about 0.00003 gallon. Therefore the above rate is equal to fifty drops per square foot per hour. From experiments on flat pieces of concrete moistened with an atomizer the rate of evaporation at a humidity of 70% averaged 0.0017 gallon per square foot per hour when the specimens appeared dry. The possibility of the disappearance of the percolating water due to evaporation is therefore established. The minimum flow for a fifty-hour period furnishing visible indication of leakage was 0.00011 gallon per square foot per hour at a humidity of 89%.

Again consider the continuous flow from the specimens run for two or three weeks, see Fig. 20; the evidence furnished by the shapes of the leakage-time curves points to flow through the specimens.

Another proof of the masking effect due to variations in humidity and consequent rate of evaporation is furnished by the tests made on specimens *PU* 288-291. These were made and cured like batch 68 except that they were tempered with 9.0% water in mixing. At an age of 56 days specimens *PU* 288 and 289 were placed on beds of calcium chloride for a period of 87 hours. They were then placed in tubs containing about 1 in. of water for a period of 346 hours. The tests of specimens *PU* 290 and 291 were made under the reverse conditions for the same time intervals. From the slopes of the tangents to the leakage-time curves in the lower portion of Fig. 20 it is found that the average rate of flow of specimens *PU* 288 and 289 decreased from 0.00020 to 0.00011 gallon per square foot per hour when the bedment of the specimens was changed from calcium chloride to water. On the other hand the average rate of flow for specimens *PU* 290 and 291 increased from 0.00012 to 0.00016 gallon per square foot per hour due to the reverse treatment.

From what has preceded it is evident that the rate of flow increases with the dryness of the atmosphere to which the specimens are exposed, but that the chance of detecting leakage by the eye becomes less as the humidity decreases.

SUMMARY.

From these tests the following conclusions applicable to concrete made of like materials may be drawn.

1. None of the concretes tested were *absolutely* watertight

if we consider continuous flow into the specimen as proof of permeability, but the majority of the mixes were so impervious that no visible evidence of flow appeared. For most purposes such mixes can be considered watertight.

2. The visibility of dampness on the bottom of the specimens increased with the humidity of the air and the non-homogeneity of the concrete. The minimum rate of flow for which leakage was indicated was 0.00011 gallon per square foot per hour.

3. In tests of nearly all of the properly made mixes of 1:7 proportions, or richer, the rate of flow for a fifty-hour period was less than 0.0001 gallon per square foot per hour under a pressure of 40 lbs. per sq. in.

4. Through increasing the fineness of the cement a reduction in the rate of flow and a considerable increase in the strength of a 1:9 mix were secured.

5. By grading the sand and gravel in accordance with Fuller's curve it was possible to obtain practically watertight concrete of 1:9 proportions under pressures less than 40 lbs. per sq. in. To secure such results, however, requires great care and careful supervision in mixing, in determining the proper consistency, in placing, and *in curing* the concrete.

6. In the proportioning of such materials as these, volumetric analysis coupled with a determination of the density and air voids yields very valuable information concerning the best proportions of sand and gravel for a given proportion of cement. If proportions must be selected arbitrarily a 1:1½:3 mix, by volume, is very impervious. It should be remembered, however, that the volume changes in rich mixes due to alternate wetting and drying are much greater than for lean mixtures. Consequently due attention must be given to the provision of expansion joints and reinforcement in structures made of them.

7. The use of the proper amount of water necessary to produce a medium or mushy consistency is one of the most important conditions in securing impervious concrete, especially when lean mixtures are used. Dry mixtures cannot be sufficiently compacted in the molds and are more difficult to cure properly than the mushy mixtures. Although the use of a wet consistency does not materially affect the imperviousness of very rich mixes, such as 1:1½:3, it greatly increases the flow through a lean mix.

8. For lean mixes made from damp sand it seems advisable to mix longer than is now common practice. These tests would indicate that for a mixer running at 30 r. p. m., a period of one and one-half to two minutes is required to secure thorough mixing of a 1:9 concrete. For a rich 1:1½:3 mix a one-minute period appears to be sufficient. The method of mixing in which water is first admitted to the mixer is to be condemned. A preliminary period of dry mixing lasting from 15 to 30 seconds seems desirable.

November, 1914

9. No stage or process in the making of impervious concrete is of more importance than curing. The results of these tests clearly demonstrate that premature drying destroys the imperviousness of 1:9 mixes, seriously impairs that of the 1:2:4 mixes and somewhat diminishes that of the 1:1½:3 mixes. For thin sections, not over six or eight inches thick, the curing conditions should be such that a lean concrete will be kept damp for a period of one month and a rich concrete for at least two weeks. Even after a month of proper curing, complete desiccation of a lean mix composed of these materials produces an increase in permeability, but the effect on a rich mix is not marked.

10. In these tests the imperviousness of the concrete increased rapidly with the age of the specimens for the first month; thereafter the change was not marked.

11. From the tests thus far made it seems probable that the permeability of lean concrete in a direction normal to the pouring is greater than in the direction of pouring.

Credit for painstaking effort in making and testing the specimens is due John Miller, Laboratory Assistant. For helping in the preparation of this report acknowledgment is made to S. D. Wonders, F. D. Bickel, W. P. Bloecher, and O. A. Bailey, students in civil engineering. Many valuable suggestions have been received from E. R. Maurer, Professor of Mechanics; C. W. Boynton, Inspecting Engineer of the Universal Portland Cement Company, and F. H. Oakes, Assistant Engineer with the same firm. The Universal Portland Cement Company donated materials for the experiments.

DISCUSSION

President Lee: I was employed on one of the early pieces of concrete construction in Chicago. At that time the literature on the subject of concrete was limited, and I remember there was considerable discussion of the question as to whether crushed stone should be screened to free it of dust. There was a battle on between the advocates of the wet mix and the advocates of the dry mix, and for a considerable length of time the battle consisted largely of words. Such questions are now pretty well settled.

We have with us tonight members who are prepared, I am sure, to discuss the paper. I will ask Mr. Finley, one of our past presidents, to open the discussion, as he is particularly well fitted to give us an idea or two.

W. H. Finley, M. W. S. E.: I am sorry there are not some other past presidents here tonight, not only for the help they would give us, but for the information they might receive from listening to the presentation of the paper.

I cannot do much more than express my appreciation of this paper. I certainly endorse the author's conclusions. The development of concrete construction has been extremely rapid, and papers of this kind, showing results of careful experiments, will reinforce some of the ideas we have always held about concrete. I was particularly impressed, on a recent trip through the East, with the improved character of concrete work as compared with work done ten years ago, due no doubt to just such experiments as have been illustrated here tonight.

I am satisfied that all engineers engaged in concrete construction have known for years that they could make practically impervious concrete by using the proper methods. Unfortunately, however, concrete cracks have occurred from expansion, contraction, and internal stresses. Where leakage would be objectionable I think it is necessary to waterproof the structure. There are a number of compounds on the market, which would make practically impervious concrete, but if cracks develop in the concrete the compound does not prevent the seepage of water. On track elevation work, where expansion joints were provided every 30 ft., I have seen cracks within 1½ ft. of the expansion joint.

J. H. Libberton, ASSOC. W. S. E.: Although covering particularly the permeability of concrete, Professor Withey has emphasized a number of other points of considerable importance. For instance, the wonderful increase in strength of the specimens which were sprinkled, over those which were allowed to stand in the open, is to be noted. Not only was the permeability seriously decreased in the specimens which were sprinkled, but the strength was so increased as to indicate that proper curing of concrete specimens is of paramount importance. So far as permeability itself is concerned, Professor Withey has shown conclusively that the proportioning of aggregate is by far the most satisfactory method of waterproofing. For some time, various authorities have insisted that the best waterproofing is care and cement; from the results it would seem that this conclusion is well founded, particularly when the principles of careful proportioning are followed.

E. B. Wilson, M. W. S. E.: I will give a little outline of some tests of waterproofing compounds conducted under the writer's attention about a year ago.

We, the American Bureau of Inspection & Tests, had occasion to look into the testing of waterproofing for the floors of a garage. The building, which was a stable with wooden floors laid on top of brick arches, was abut 100 ft. by 400 ft. and four stories high. The idea was to replace the wooden floors with concrete in such a manner as to prevent leakage when washing the automobiles. The only idea in these tests was to investigate the water-resisting qualities of certain mixes of concrete with and without the addition of waterproofing compounds, including clay. The matter of leakage through contraction cracks, etc., was not given attention. Following is the report, with a few revisions, as rendered to our client:

> "The permeability and crushing test specimens were all made to conform as nearly as possible to conditions found in

the actual practice of laying concrete floors under specifications similar to those formulated for the work.

"The specified mix for the base of the floors was 1 part cement, 1½ parts sand, and 3 parts crushed stone. The base concrete used in test specimens was 1 part cement, 2½ parts sand, and 5 parts crushed stone. The topping, instead of being 1 part cement, ¾ parts sand, and ¾ parts of crushed granite, per specifications, was made 1:1:1.

"The penetrations of the toppings through absorption and hydrostatic pressure combined were so slight in the permeability tests that further tests for absorption were considered unnecessary.

PERMEABILITY TESTS OF WATERPROOFED CONCRETES.

"All permeability specimens were 8 in. square and 3 in. thick. The base was 2¼ in. thick and was formed of concrete made of 1 part cement, 2½ parts torpedo sand, and 5 parts ¼ in. to 1 in. crushed limestone. The topping was ¾ in. thick and was made of 1 part cement, 1 part torpedo sand, and 1 part ¼ in. crushed granite (no dust). All mixes were of quaking consistency except No. 1 (the only one in which an iron dust floor hardener was used), which was made and placed quite dry by a representative of the manufacturer of the hardener: all other mixing and finishing was done by an experienced floor finisher. Universal cement (Lot 1737) was used throughout. except a different cement was used in test No. 4.

"The specimens were soaked twice a day for four days and were stored in ordinary atmosphere for the entire period. May 12th to 16th, 1913, until beginning of tests, Sept. 19th, 1913.

"The top surface (granite topping) of each specimen was given a coat of tar paint with the exception of a space 5 in. in diameter in the center left clear for the application of pressure.

"The specimens were mounted on cast iron flanges 1½ in. thick, 12½ in. outside diameter and 5½ in. inside diameter. The untreated 5 in. circular space on the top of the block was centered on the 5½ in. hole in the casting. The hole in the casting was reduced to ½ in. and connected with the pressure line. A mixture of 1 part hot pitch and 2 parts fine sand was used as a seal between the contact surfaces of the specimen and the casting.

"The apparatus used and the method employed for applying the hydrostatic pressure was similar to that described in Technologic Papers No. 3 of the U. S. Bureau of Standards. with the exception that the specimens were so mounted in iron rings that the moisture coming through could be accumulated and the surface of the blocks covered to eliminate, as far as possible, any evaporation of the water passing through.

PERMEABILITY TESTS OF WATERPROOFED CONCRETES

SPECIMENS—Made May 12-16, 1913.
PRESSURES—(1) 4-inch head—72 hours.
(2) 35 ft. head—48 hours.
(3) 70 ft. head—24 hours.
(4) 210 ft. head—¼ hour.

TESTS—started Sept. 19—finished Sept. 29.
(5) No pressure—¼ hour.
(6) 270 ft. head—1½ hours.
(7) No pressure—39 hours.
(8) 256 ft. head—5 hours.

Test No.	Compound	Compound Added to Concrete	Results at Completion of Tests
1	Floor Hardener.........	Base: None. Topping: 5% of cement by weight.	Water penetrated topping ½ inch.
2	Powder No. 2..........	Base: 2% of cement by weight. Topping: Same as base.	Water penetrated topping ½ inch.
3	Liquid No. 3...........	Base: 7% of water by volume. Topping: 8.3% same.	Water penetrated topping ⅜ inch.
4	Powder No. 4...........	Base: 1.5% of cement by weight. Topping: Same as base.	Both topping and base were wet throughout. See note.
5	Plain	Base: None. Topping: None.	Water penetrated topping ½ inch.
6	Clay	Base: 10% of cement by weight. Clay= 100 lb. cu. ft. Topping: Same as base.	Water penetrated topping ⅝ inch.
8	Paste	Base: 6.6% of water by volume. Topping: 8.3% same.	Water penetrated topping ¾ inch.

Note:—Moisture (small spots) first appeared under 35 ft. head 78 hours after tests were started or six hours after head was raised from 4 in. to 35 ft. One hour later two additional spots appeared. All spots increased in size gradually and three hours after appearance of first drops of water formed; 18 hours afterward the whole top surface was moist and several large drops of water had formed. Under 70 ft. head the accumulation of water appeared to decrease rather than increase (probably caused by decrease in flow, or by cessation of flow and evaporation). The specimen dried off during the 39-hour suspension of pressure before 256 ft. head was applied and at the termination of pressure of that head (end of test) about as much moisture had accumulated as was in evidence before the pressure was suspended. The water which exuded from Test No. 4 specimen had a soapy appearance; this specimen was more porous than the others. They were all broken for examination.

COMPRESSION STRENGTH OF WATERPROOFED CONCRETES

SPECIMENS—Six-inch cubes, three months old, they were made at the same time and topped and stored the same as the specimens for permeability and absorption tests.

PRESSURE— Pressure was applied in the direction of the tamping. In all instances failure occurred in the base.

Test No.	Compound	Compound Added	Weight Lb. per Cu. Ft.	Compression Strength, Lbs. per Sq. In.		
				High	Low	Aver.
21	Floor Hardener	Base: None. Topping: 5% cement by weight.	152	3540	3420	3480
22	Powder No. 2	Base: 2% of cement by weight. Topping: 2% of cement by weight.	146	4090	4020	4055
23	Liquid No. 3...........	Base: 7% of water by volume. Topping: 8.3% of water by volume.	146	4460	3590	4130
24	Powder No. 4..........	Base: 2% of cement by weight. Topping: 2% of cement by weight.	145	4240	4100	4170
25	Plain	Base: None. Topping: None.	145	4200	3790	3995
26	Clay	Base: 10% of cement by weight. Clay=100 lb. cu. ft. Topping: Same as base.	146	4440	4100	4270
28	Paste	Base: 6.6% of water by volume Topping: 8.3% of water by volume.	149	3720	3550	3635

TENSILE STRENGTH OF WATERPROOFED MORTARS.

MIXTURE:—1 Part Cement: 3 Parts Standard Testing Sand.

Test No.	Compound	Compound Added	Water Used by Weight	Tensile Str'gth, Average. Lbs. per Sq. In.	
				7 Days	28 D'y
41	Floor Hardener	5% of cement by weight	9.3%	250	400
42	Powder No. 2	2% of cement by weight	9.3%	242	378
43	Liquid No. 3	8.3% of water by volume	9.3%	168	293
44	Powder No. 4	1.5% of cement by weight	9.3%	178	300
45	Plain	None	9.3%	255	402
46	Clay	10% of cement by weight	9.7%	297	415
47	Clay	5% of cement by weight	9.6%	258	405
48	Paste	8.3% of water by volume	9.3%	267	382
49	Paste, 1:2 mix	8.3% of water by volume	10.5%	412	517
50	Powder No. 4	2% of cement by weight	9.3%	227	342
51	Neat cement	Universal, Lot 1737	23.0%	560	660

TENSILE STRENGTH OF WATERPROOFED MORTARS.

SPECIMENS:—Standard 1 in. square briquettes made with aggregates in proportions shown. Universal Cement (Lot 1737) was used throughout except another cement was used with Powder No. 4. Test No. 34 (machine mixed); sand and granite were the same as used in permeability tests.

MIXTURE:—1 Part Cement: ¾ Parts Sand: ¾ Parts Granite.

Test No.	Compound	Compound Added	Water Used by Weight	Tensile Str'gth, Average. Lbs. per Sq. In.	
				7 Days	28 D'y
31	Floor Hardener	5% of cement by weight	11.5%	503	680
32	Powder No. 2	2% of cement by weight	11.5%	478	643
33	Liquid No. 3	8.3% of water by volume	11.5%	453	613
34	Powder No. 4	1.5% of cement by weight	11.5%	397	632
35	Plain	None	11.5%	493	705
36	Clay	10% of cement by weight	11.5%	478	658
37	Clay	5% of cement by weight	11.5%	475	612
38	Paste	8.3% of water by volume	11.5%	472	618
39	Paste, 1:1:1 mix	8.3% of water by volume	11.5%	438	622
40	Powder No. 4, 1:¾:¾ mix	2% of cement by weight	11.5%	495	690

CONCLUSIONS

Results in general on these compounds, including the plain mixture and mixtures in which clay was used and excluding "powder No. 4," do not in my opinion warrant the selection of any one over the others. The plain 5% clay and 10% clay averaged fully as well as the special compounds. Liquid No. 3 gave somewhat lower tensile results than the average, but on the other hand it gave the highest individual compression results of any of the specimens crushed.

These tests, while quite limited in scope, seemed to bear out the contention that good workmanship and proper cement and aggregates are the chief requisites for making a waterproof concrete.

F. E. Davidson, M. W. S. E.: The paper presented this evening is one of the most interesting papers I have had the pleasure of following for sometime, and I have listened to the discussion with much pleasure.

I would like to know whether or not the University expects to make some further tests using other brands of cement. I take it that the Universal Portland Cement Co. is back of these tests, and in this connection I will refer to a statement I made on this floor some three years ago, to the effect that I could not conceive of any greater work that the great corporations could do than to assist the state universities and experimental stations in making tests along the lines outlined by the paper tonight.

My own experience with Universal Portland cement leads me to believe that it will act somewhat differently under certain conditions than other well-known brands of cement. In this connection I will call attention to an experience I had with waterproofing some months ago. I designed a building, the roof of which was to act as a storage yard for pig iron for a foundry, and was to carry a live load of 1,500 lb. per sq. ft. It was evidently impossible to put on any one of the usual kinds of roofing, and it became necessary to use concrete that was waterproofed. We used for 1½-in. wearing surface a 1 to 2 mix of Portland cement and aggregate. The aggregate was composed of 1½ parts of screened granite screenings, and ½ part of torpedo sand, to which a small amount of ironite was added. The first winter no difficulty was experienced. However, the unequal loading on the column footings, due to the heavy pig iron, caused an unequal settlement, with the result that cracking occurred in the concrete over the girders. These cracks were waterproofed by using a grout composed of Portland cement, fine sand, and ironite.

A problem which is, I believe, of more importance to the engineering and architectural professions at the present time than that of the permeability of concrete, is the problem of preventing the dusting of the wearing surface of concrete floors. I have discussed this matter with various engineers who have had experience in building work where the floors were not in the immediate presence of moisture, and we earnestly hope that some university or some engineer will very soon be in a position to offer some method to overcome this difficulty.

Professor Withey: In reply to Mr. Davidson, I will say that there will be several other brands of Portland cement used in these permeability tests. We have no intention of narrowing our investigation to the results which would be obtained from one brand. I wish to state that the Universal Portland Cement Co. has been very liberal in furnishing materials for this investigation and has agreed that the University shall have the right to the publication of the results.

I should also like to call attention to the small effect of long storage of the cement in our air-tight, galvanized iron bins. This is well brought out by a consideration of the results in Table No. 1. It will be observed that after a period of two years a difference in water strength of this cement was very slight.

ARITHMETICAL MACHINES

H. E. GOLDBERG, M. W. S. E.

Presented October 5, 1914.

HISTORICAL.

The first arithmetical machine was invented, as far as I know, by Blaise Pascal, about 1641. Pascal, you will recall, was the wonderful Frenchman, who at the age of sixteen discovered the theorem in conic sections called Pascal's Hexagram. He was not only one of the foremost mathematicians of his day, but also excelled in mechanics. At the age of nineteen he produced the first machine with mechanical means for the carrying of the tens. Immediately the field of calculating machines became fertile ground, and many inventors cultivated it.

The next notable production was by Leibnitz, about 1671. He built several multiplying and dividing machines, and a good description of one, constructed about 1700,—the first in which a multiplicand could be set up and preserved during the process of multiplication,—is available. But this machine was never put on the market. In some of its features it resembled the Thomas machine of later years, which was a well-designed and well-constructed multiplying and dividing machine built by Thomas and marketed in Europe about 1820, and which is still in use.

Up to that time inventors had been modest and were satisfied with making simply multiplying and dividing machines, but about 1825 Charlels Babbage of England became bolder, and built a difference engine. Let me recall to you that the series of integral values of any rational algebraic polynomial can be calculated by the method of differences. This is shown in algebra. It is true that many other functions, for instance logarithms, can be calculated by the same method of differences. The method will not apply throughout the whole series of logarithms but does apply with sufficient accuracy for a group of a large number of consecutive terms. Thereafter a new start is made for another group. Babbage invented his machine intending originally to apply it to the calculation of logarithms, as well as to the calculation of all sorts of nautical and astronomical tables. When he was about half through with his first or difference machine he decided that it was not good enough, and invented what he called the analytical engine —a calculating machine that could compute any arithmetical results that could be computed by a human being. For instance, it would extract square root, cube root, solve equations by Horner's process, and so on. However, this machine was never built. The principle on which it depended was similar to that of the Jacquard loom. Many of you have doubtless seen, say at Riverview Park, a machine, controlled by a series of cards pierced with holes, which weaves a portrait, say of George Washington. Babbage proposed to juggle with numbers in the same manner as the Jacquard loom juggles with threads. It was a most ambitious project, but was not fulfilled. I have read his book and studied some of his mechanisms. They are not as simple as they might be. Babbage claims, incidentally, that to meet the necessities of his work, he was the first to graduate the screws of the slide rests of his lathes. He spent a considerable sum of money advanced him by the Government of England, as well as his own fortune, without completing any machine.

Another commercial advance we find in about 1878, when the Russian, Ohdner, put on the market the machine that is now called the Brunsviga, and is also marketed under the names of the Marchand, the Thales, the Triumphator, the Teitzgen, etc.

In this country, I believe the first patent on calculating machines issued by the Patent Office was to O. L. Castle, of Alton, Ill., about 1850. It was for a ten-key adding machine, which did not print. It added in only one decimal column, helping a bookkeeper to add up, say, the units column of a long account. It could then be used for the tens, and so on. We find, quite early, key machines having a keyboard like the present Burroughs keyboard, namely 81 keys. Riggs, in America, shows such a machine about 1854. It is astounding how early some ambitious projects were launched. For instance, in 1871 we find that Teasdale invented a machine for multiplication. Suppose it were desired to multiply 4892 by 7926. Put the multiplicand and multiplier in the machine, turn the crank, and, presto, there is your answer! No such machine has yet been put on the market, although attempts have been made in that direction. About 1888 the first Burroughs machine, which both added and printed, appeared on the market. It was quite unlike the present type, which dates from about 1893. In 1888, we find the first typewriter attachment, invented by Ludlum. The Duplex Comptometer, invented by Dorr E. Felt, was put on the market about eight years ago.

Many patents on calculating machines have been issued by the Patent Office. I once ordered copies of only a portion of the number issued, intending to read them, but when I saw what a large number there are, I realized that I would probably die of old age before I completed reading them. Under the circumstances, it will therefore be impossible for me to refer to any more than a few of the mechanisms described. Moreover, for the purpose of convenience, the sketches which I have made are diagrammatic, and follow no particular machine, so that if any machine representative should think I have done him an injustice, let him remember that his machine is different.

MECHANICAL.

ADDING MACHINES.

Following is an attempt to describe some of the mechanisms by means of which addition is accomplished. Our system of numeration is a decimal system. We count in cycles of ten. After reaching ten, we start again to twenty, then to thirty, and so on. Of course, we have exceptions, namely eleven, twelve and thirteen. Logically, however, we should say ten-one, ten-two, and ten-three. While we are able to twist ourselves and our minds into all sorts of knots, mechanism refuses to be so accommodating, and in a decimal mechanism eleven is always ten-one and nothing else. We find that almost all arithmetical machines represent the number by mechanical cycles corresponding to ten, namely, totalizer wheels each provided with teeth some multiple of ten; for instance, the wheels have ten teeth, twenty teeth, thirty teeth, etc. (Let me state here that arithmetical machines calculating with Arabic numerals have been made without the numbers being represented on wheels. In fact, one machine, Mr. Bricken's, has no wheels whatever.) In totalizers where the number is supposed to be read off by the operator, it is customary to supply the wheels with the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. In machines where the number on the wheels is not read by the operator, the digits are not supplied. For instance, the Burroughs has digits on its totalizer while the Dalton has not.

What means are used in putting a number into an arithmetical machine?

DIRECT NUMBER INSERTION.

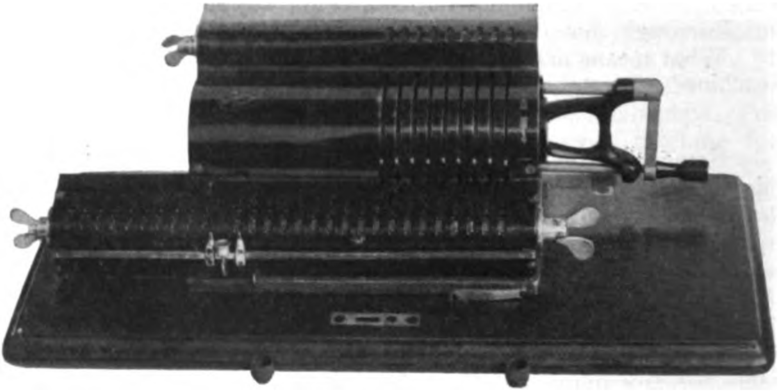
Some machines, for instance the Triumph, are nothing but big totalizers; the totalizer wheels are so large that the operator has room enough to place his fingers through a window into the spaces between the teeth of the wheels. The machine is furnished with dials indicating where the operator is to place his finger for a 1, for a 2, etc. After properly locating the finger, the operator pulls it down as far as it will go, that is, until he strikes the bottom of the window. He thus rotates the engaged totalizer wheel one step, two steps, or any number that he desires. This is certainly the most direct method and was the one used by Pascal in 1641. Certain miniature machines working on the same principle have been built, but instead of using the finger, a pencil or sharp steel point called a stylus is placed through the window between the teeth of the wheels. Among the latter machines are the Arithstyle, the Rapid, and the Gem.

Let us put the number 132 into the machine. We place the finger in the 1 location of the hundreds wheel, and pull down. We then put the finger in the 3 place of the tens wheel, and pull down. And so on. The capacity of the machine is, of course, determined by the number of totalizer wheels, of which I have represented only two.

Carrying Mechanism: Each totalizer wheel is supplied somewhere on its circumference with a variation which mechanically determines the location of the carrying point and which arithmetically corresponds to the 0. The first step away from the 0 is 1, both mechanically and arithmetically, the second step, 2, and so on. This variation on the totalizer wheel is ordinarily a projection like a pin, as in the Wahl, the Burroughs, the Brunsviga, and other machines. On the other hand, it may be, instead, a drop or fall, or a cut, as in the Howieson and other machines. Of the various carrying mechanisms possible I will now explain the principle of the one illustrated in Figs. 1 and 2. Something similar is used in the Wahl machine.

In the totalizer, there are two sets of gears, the totalizer gears proper *T*, and the intermediate wheels *B*. Each totalizer wheel has, as shown in Fig. 1, forty teeth and a projection *P* to the left for each ten teeth. The number of teeth upon the intermediate wheels is of no importance. If one of the wheels *T* be rotated, then in due time its carrying projection *P* will engage the coöperating wheel *B*, which will be turned, and which will thus turn one step the next higher wheel *T* to the left.

Let us mentally add the numbers 132 and 654. (Fig. 3, Ex. 1.)



Brunsviga Machine.

We start from the units and say 2 and 4 are 6; 3 and 5 are 8; 1 and 6 are 7. The answer is 786. In this particular example no carrying of the tens occurred. The process that did occur seems to have no universally accepted name, and I will term it accumulation. Take another example. (Fig. 3, Ex. 2.) Add 9999 and 1. Again starting from the units decimal place, we say 9 and 1 are 10, put down 0 and carry 1. We then go on, and in the tens decimal place say 9 and the carried 1 are 10; put 0 down and carry 1. In the hundreds again, 9 and the carried 1 are 10; put down 0, carry 1; and so on to the end, where we put down the last carried 1. The addition of the numbers 9999 and 1 requires practically nothing but tens-carrying. Let us take still another example. (Fig. 3, Ex. 3.) Let the two numbers to be added be 9999 and 9999. We say in the units place, 9 and 9 are 18; put down 8, carry 1; and so on. We see that in every decimal place from the units on there occurs both accumulation and carrying.

No new process is discovered. It will be found that addition is composed of only these two, namely accumulation and carrying. Let us refer again to the third example. In the units place we say, 9 and 9 are 18; put down 8 and carry 1. In the tens place we say, 9 and 9 and the carried 1 are 19; put down 9 and carry 1; and so on to the end. Let me call to your attention that in this process we first accumulate, then tens-carry, then again accumulate, then again tens-carry, and so alternate one with the other to the end.

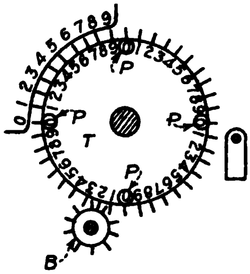


FIG. 1

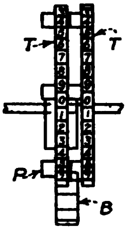


FIG. 2

That is, both the accumulation and the carrying are successive; each follows the other, and only one is done at a time.

On account of the limitation of the human mind, we in school are taught to add by doing one thing at a time. In addition as shown above, we accumulate and tens-carry singly and successively. The Wahl totalizer, however, is not so limited. It carries in all the decimal places simultaneously, but accumulates in only one decimal place at one time, that is, successively.

Ex.2

9999
1
10000

Ex.3

9999
9999
19998

9999
9
18999
9
19899
9
19989
9
19998

Ex.1

132
654
786

FIG. 3

Now consider the third example from the standpoint of this totalizer. The totalizer is supposed to have already absorbed the first number, 9999, and the following description of the operation deals with the process of absorbing and digesting the second number:

First, the totalizer receives (as before described) the 9 of the thousands place. This immediately mixes with the contents already in its stomach, namely, the first number. The bite is simultaneously digested, and the result is 18999. A second bite is taken, and digested during the swallowing. The result is 19899. The 9 in the tens place is swallowed, and the result is 19989; and when the last 9 has been absorbed the result is immediately 19998. In the second example it would make one bite of the 1 in the units place, carry simultaneously throughout all its decimal places, and be completely done.

Machines whose totalizers act as just described are found among the typewriter attachments, of which the Underwood Computer as well as the Wahl, are examples. The first typewriter attachment patented by Ludlum in 1888 operated in the same manner.

Locking Mechanism: The above is the principle of the carrying mechanism. In practice, many additional features are supplied, some of which I will point out. The quick movement of a wheel *T* will cause its projection *P* to strike the intermediate wheel *B* quite sharply, which thereupon will rotate the next higher wheel *T*, not only one step, as required, but perhaps several superfluous steps. A mistake will thus be made. To prevent such mistakes, locking mechanism is introduced. In the Wahl machine the locking mechanism is composed of Geneva gearing. This locking Geneva gearing in its turn requires unlocking mechanism, so that the final result is far more involved than the above sketch indicates. In the Underwood-Wright machine, which uses a similar carrying mechanism, overthrow is prevented by a set of spring pawls. These check the momentum of the flying wheels, but, of course, they also interpose a resistance against the free starting of the wheels, which in turn leads to motor mechanism to drive them.

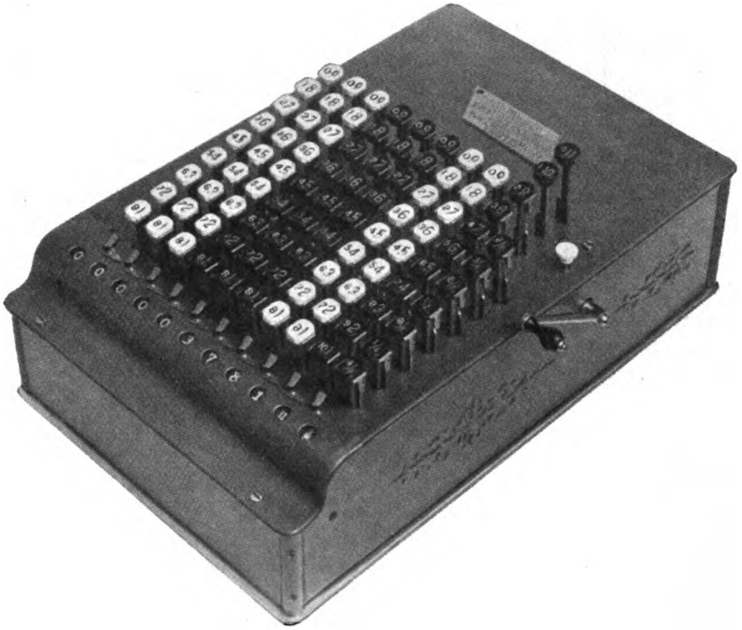
You will notice that the above carrying mechanism is reversible. It will work just as well if the wheels *T* are rotated one way as the other. It therefore can be and is used for both addition and subtraction, subtraction being accomplished by rotating the gears *T* in the direction opposite to that for addition.

Figures 1 and 2 show only two wheels *T* and only one wheel *B*. In practice there are totalizers with up to twenty wheels *T* and therefore nineteen wheels *B*. Please note that in order to function correctly, only one wheel *T* at a time can be used for the insertion of the number. Pulling all four wheels down at once to add 9999 to 9999, would result in a mistake. This is because the carrying movement of the wheel *B* would take place at the same time as the accumulating motion of the wheel *T* and would thus be lost. To function correctly, all those wheels to the left of the particular wheel which is used for accumulating must be held in reserve in order to properly carry the tens. All the wheels to the right must be held non-interfering. Any carrying that does take place is, however, theoretically transmitted simultaneously throughout all the higher wheels to the left, and not successively as in the carrying mechanism to be described. The totalizer accumulates successively, but carries simultaneously.

KEYS.

When we come to the subject of keys, we find two distinct and contending camps. There are what are called the 81-key machines and there are the so-called 10-key machines.

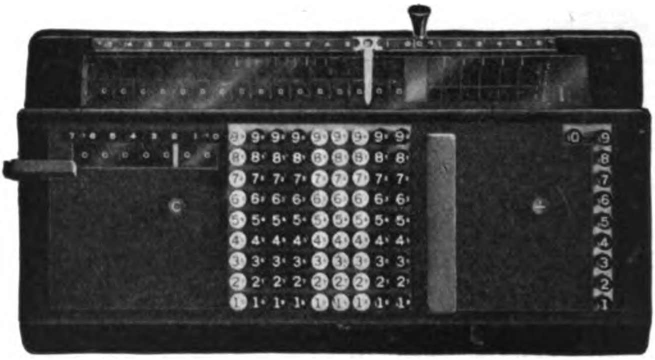
The keyboard of the 81-key machine is supplied with a number of banks of keys, say nine, each containing the keys 1, 2, 3, 4, 5, 6, 7, 8 and 9. There is a bank for the units demical place, another bank for the tens, and so on. Notice that the zeros do not occur at all. In using such a machine the operator places his finger on the proper key in the proper decimal place, and pushes.



Comptometer.

For the number 1085 he places his finger on the 1 key of the thousands bank, on no key in the hundreds bank, on the 8 key in the tens bank, and on the 5 key of the units bank. He might operate with only one finger or with all the fingers; with the fingers one at a time or all together. Operators become expert on these machines, and I have seen them use sometimes the highest figure first and units last; again, units first and the highest figure last; and sometimes a mixed order. Among the machines that have 81 keys are the Burroughs, the Comptometer, the Comptograph, the Ensign, the Wales, etc.

The 10-key machines have no sets of banks of keys, but are provided with only one set of 10 keys, namely 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9, and this set of keys is used for *all* decimal places. Here the 0 must be used. In writing a number like 11, the 1 key is struck twice. In writing 101, the operator would strike, in order, the 1, the 0, and again the 1 key. The most prominent 10-key machines on the market are the Dalton, the Moon-Hopkins, and the typewriter-adding machines like the Wahl, the Elliott-Fisher and the Underwood.



Ensign Machine.

Keyboard adding machines can, however, be divided according to their construction into key-driven and key-set machines.

KEY-DRIVEN MACHINES.

The simplest key-driven mechanism is one something like the old Comptometer. (You will pardon me if I do not describe the actual construction of any machine, for in that way I cannot so easily be caught in an error. Besides, in the actual machine, the mechanism occurs in several layers, which cannot be so readily understood as a diagram laying it out in one plane.)

Reference to Fig. 4 will show that there are as many banks of keys as there are decimal places. In each bank there are nine keys, to which are given the values 1, 2, 3, 4, 5, 6, 7, 8 and 9. Each key is normally kept up by a spring. Underneath them a lever *GL* is extended, with a gear attached thereto. Normally it is held up by a spring. There is another lever *PL*, which coöperates with a pawl, that can be inserted in a gear *T*, which is in chain with the gear upon the gear lever. When a key is pushed down, there occurs initially some lost motion; that is, the key does not strike anything. A little later a projection *a* on the key strikes the gear lever *GL* and moves it. Just when the gear lever has moved an amount corresponding to the value of the key pushed down, the bottom of the key strikes the pawl lever *PL* and pushes the pawl into the teeth of the gear *T*, thus preventing overthrow. The gear lever thus has been pushed down by a key a number of steps equal to the value of the key. Namely, the 1 key has pushed the gear lever down one gear step, the 2 key two gear steps, etc., before locking occurs. There is a ratchet mechanism (not shown) between the gear lever and the totalizer wheel *T*, so that on the way up the gear lever does not rotate the wheel of the totalizer.

The above is practically the mechanism of the Ludlum machine and of the old Comptometer. In the new Comptometer some modifications have been introduced. For instance, the gear lever does not rotate the totalizer wheel on the down push of the lever, but on the return thereof. Again, there are two pawl levers, instead of one, permitting the making of a portion of the mechanism twice as large and therefore stronger.

In the old Comptometer, the carrying mechanism upon the wheels *T* was something as follows: (Fig. 4.)

Each totalizer wheel *T* was supplied with a cam *B*, which gradually extended further and further from the center, and which was provided with a sharp drop at one point. The drop was located at the point corresponding to 9. The cam coöperated with a tooth *C* on a lever *D*. The lever had at its outer end a pawl *E*, which could drive a ratchet wheel on the next higher wheel *T*. As the lower wheel *T* rotated, its cam gradually pushed back the lever *D*, storing energy in the spring *G*. When the drop of the cam *B* passed under the tooth of the lever, the latter was no longer resisted, whereupon it flew in, and by means of its pawl *E* pushed the next higher wheel forward one step. This carrying mechanism is irreversible; that is, it will not work if the wheel *T* rotates in the opposite direction; it accumulates successively and carries successively. It was used in the Comptometer, the Dougherty, the Fisher, and the Howieson machines. In the present Comptometer a modification of this older carrying mechanism is used, which still employs the cam and sudden drop.

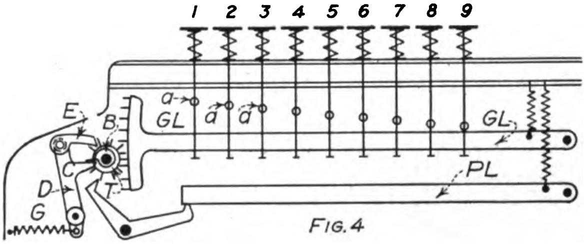


FIG. 4

Full-Stroke Mechanism: Let me call your attention to the fact that in the above machine, if the operator incompletely depresses any key, he will turn the totalizer wheel an insufficient amount. He will thus register a mistake in the machine. Such is actually the case with a good many machines on the market; for instance, the Burroughs non-listing machines. To prevent such a mistake, various mechanisms called "full-stroke" have been provided. They operate about as follows: (Fig. 5.)

Let *K* be a key with teeth on its edge. Let *B* be a pawl which by means of a spring *C* always tends to return to its central position if displaced. Obviously, the key can now move down, but the moment its teeth engage the pawl, the latter swings down assuming a position as drawn at C^1, and prevents the key from rising. However, when the ratchet has moved completely past *B*, then the latter snaps up and the key is then free to move up again. Full-stroke mechanism is in use on the handles of many adding machines, for instance the Burroughs. It is also in use on multiplying machines such as the Brunsviga. Something similar is used as a part of the full-stroke mechanism of the keys of the Wahl.

Single-Key Mechanism: There are other troubles that are encountered in the operating of the keys. Suppose the operator inadvertently strikes two keys at once. What happens? In some machines, in fact in most machines, the result is a mistake. In others, the Wahl for instance, it is impossible for the operator to depress two keys at once. This is prevented by what is called a single-key mechanism, constructed somewhat as follows:

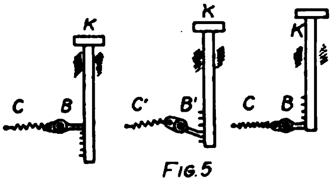


Fig. 5

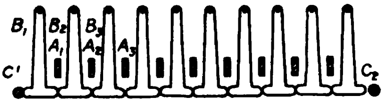


Fig. 6

Let A^1 and A^2 (Fig. 6) be the cross sections of two key levers of a typewriter. Hanging between the key levers are some pieces B^1, B^2, B^3, whose width is equal to the distance between the centers of the key levers. On the outside of all the pieces *B* are two stops C^1 and C^2. The pieces *B* occupy all the room between the stops except the thickness of one lever *A*. Thus if one lever, say A^1, be depressed, it shoves B^2 and B^3, etc., to the right and B^1 to the left, and then continues without any interference. Should the attempt be made to shove two levers down simultaneously, they jointly take up too much room, and therefore both get jammed. The single-key mechanism is extensively used, not only on adding machines, but in cash registers and voting machines. Some of you must have wondered how it is that in the Chicago voting machines it is possible to vote for, say, only 10 out of 150 candidates. It is by an extension of the above mechanism.

KEY-SET MACHINES.

In the class of key-set adding machines are to be found some of the best known machines, such as the Burroughs and Wales. The Burroughs is constructed about as follows: (Figs. 7 and 8.)

There is a bank of keys for each decimal place. Each bank is provided with keys having the values 1, 2, 3, 4, 5, 6, 7, 8 and 9. Coöperating with the keys of each bank is a bar *A*, which has a series of projections upon it, P^1, P^2, P^3, up to P^9. Notice that P^1 is very close to the bottom of the key 1, in fact, just one step removed. P^2 is two steps from the bottom of the key 2; P^9 is nine steps from the bottom of key 9. There is a spring *C* tending to move the gear bar to the left, but it is prevented from so moving by the interference of the cross bar *D*. When the operator depresses a key, he pushes its bottom into the way of the coöperating projection upon the bar. The operator, having thus set up the keys for the number desired, pulls the handle. This advances the bar *D* to the left, thus removing its interference. The bars *A* follow the bar as far as they can, that is, until each bar hits the projection upon the key depressed in its bank. Each bar is thus advanced a number of steps corresponding to the value of the key depressed. Some of you have already noticed the fact that if no key is depressed there is nothing to stop the gear bar in its advance. It therefore would move the maximum amount, say nine. Of course, this must be prevented in an actual machine, and is so prevented by a special stop which prevents the bar *A* from moving, but which stop is pushed out of the way by the pushing down of any key in the bank.

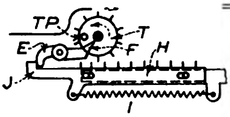


FIG. 8

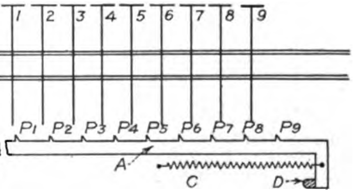


FIG. 7

TOTALIZER.

You will notice that Fig. 8 is drawn to a larger scale than Fig. 7. This is for the purpose of illustrating the totalizer. During the advance of the gear bars, the totalizer wheels *T* were not in mesh with them. After the bars have finished moving leftward, the totalizer is lowered into mesh with the bars. When the cross-bar *D* is pushed back, it pushes back the gear bars to their original place, and the meshed totalizer wheels are thus rotated an amount corresponding to the value of the keys set up.

Immediately after the rotation of the totalizer wheel by the gear bar, the carrying mechanism operates. The tens-carrying mechanism is constructed somewhat as follows:

Imagine the totalizer wheels *T* mounted on an axle and each wheel provided with a carrying projection *TP*. Between each two wheels is a lever *E* mounted, let us say, friction-tight upon its fulcrum, and having a tooth *F* in the pathway of the pin *TP*. The wheel *T* rotates in the direction of the arrow, and in due time its pin *TP* will strike *F* and push away the lever *E*. This striking and pushing away of the lever is due notice that the wheel has completed a cycle of motion; that is, arithmetically, it should carry a ten into the next higher wheel to the left. Any wheel that should tens-carry will therefore have pushed away its lever. Any wheel that should not tens-carry will not have pushed away its lever. The wheels *T* are rotated by the racks *H* upon the bar *A*, which racks *H* in their turn are pulled by springs *I* fastened both to the racks and to the bar *A*. Each rack *H* is provided with a hook *J* that strikes against the end of the lever *E* whenever that lever is in its approached position; that is, as long as the lever has not been pushed away by the wheel. But when the lever *has* been pushed away by the wheel, the hook *J* no longer strikes the lever *E*. Instead, it enters below the lever, and thus moves one step further to the right than it would have moved if it had struck the lever.

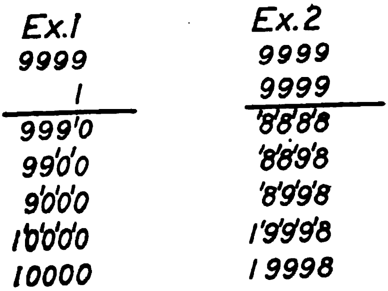


Fig. 9

Notice that each rack *H* is stopped by the lever *E* which is at its right, which lever in turn is moved by the totalizer wheel *T* at its right. That is, finally, the striking of pin *TP* of a wheel against its lever determines that the wheel next to the left shall receive not only the movement which it would otherwise receive, but also an additional step of movement; that is, the tens have been carried into it.

The above mechanism is almost identical with that used in the Burroughs and the Dalton machines. Variations are found in the Moon-Hopkins and many others. The mechanism as described is irreversible; that is, it will not work if the wheels *T* rotate in the opposite direction. The wheels would be stuck when the pin *TP* would strike *F*. This sticking of the wheel at this point when rotating in the opposite direction is used in the above machines in bringing said wheels to the zero position, as in erasing a number on a totalizer or in the printing of a total. The tens-carrying of this mechanism is, of course, successive. The wheel to the left does not carry until the wheel to the right has done so, but it is very rapid, and in practice but little time is occupied thereby.

A totalizer like the above that accumulates simultaneously, but that carries successively, would digest the examples previously used in the following manner: (Fig. 9.)

Having already in its stomach the first number, 9999, it swallows the second number as a whole, but does not assimilate it immediately. The result as to the first bite would be ('8), ('8), ('8), ('8). The little (') shows that it is a number temporarily stored up to be afterwards carried. Mechanically it means that the lever next to the wheel has been pushed away. A series of digestive steps now occur, which successively transform the contents into the number desired. The first digestive step results in the carrying of the units (') into the tens, thus giving ('8), ('8), ('9), 8. That is, the tens rack has moved an extra step. The second digestive step produces ('8), ('9), 98. That is, the hundreds rack has moved an extra step. The third step shows ('9), 998. And the last step produces 19998.

Millionaire Machine.

The totalizers of many machines operate on this principle of delayed seriatim carrying. Among them are the Burroughs, the

Moon-Hopkins, the Dalton, the Wales, the Barrett, the Morse, the Ensign, the Brunsviga, the Marchand, the Tim, the Millionaire, the Monroe, and the Archimedes.

Any machine whose totalizer would accumulate and carry simultaneously would make but one bite of the whole meal. Thus 9999 and 9999 is 19998. There are no machines on the market whose totalizers operate on that principle, but there are quite a number described among the patents issued in the United States. Let me state here that one mechanical basis for the possibility of accomplishing all the accumulations and all the carryings simultaneously rests on the employment of trains of epicyclic gears.

TEN-KEY MACHINES.

Let us go a little further into the theory of the ten-key machines. We noted that every totalizer has a set of totalizer wheels, one for units, one for tens, another for hundreds, etc. When on a typewriter a number is printed in a column, as in arranging dollars and cents properly, it is the business of the operator to bring the carriage of the machine to the proper place for the first figure, and from then on they follow in proper order. This readily solves the problem for all typewriter attachments such as the Wahl and the Elliott-Fisher. On some machines, however, as the Dalton and the Moon-Hopkins, there is no carriage which is first decimally placed by the operator. When on such a ten-key machine an operator strikes a 1, how does the machine know that it is a 1? Perhaps it is only the first figure of a number, say 127. Historically, the accomplishing of the result was found difficult, as is shown by the fact that in the earlier machines the inventors put down the figures backward. Thus 127 used to be put down, first 7, then 2, then 1. The first men to show mechanisms which permitted the figures to be written down highest figure first, units last, were Mr. McCaskey

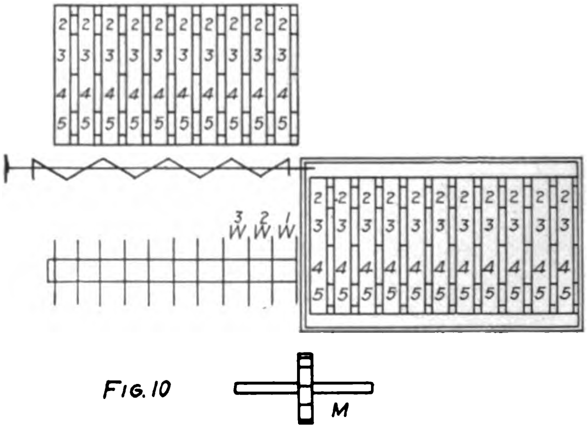


FIG. 10

and Mr. Helmick, both now of Chicago. The idea occurred to each of them independently, and as they both applied for patents in 1894, some complications arose as to who was the inventor. The means by which they accomplished the result was the introduction of a supplementary carriage capable of storing up a number. (Fig. 10.)

Let there be a series of windows through which numbers become exposed to the operator of a machine. Let W^1 be the units place window, W^2 the tens place, etc. Let A be a carriage something like the carriage of a typewriter, and provided in a similar manner with an escapement mechanism, and having a tendency continually to travel to the left. This carriage is provided with a set of wheels B. Let M be a master wheel located immediately to the right of the units window. The master wheel M is given a rotation corresponding to the figure desired. If the figure is an 8, the master wheel would be rotated eight steps by any suitable mechanism. This master wheel M thus rotates the leftmost wheel of the carriage, bringing the figure 8 opposite to the row of windows, but not yet under the window in sight of the operator. When the operator releases his finger from the keys, the escapement mechanism of the carriage causes the latter to advance one step to the left. The 8 therefore comes into view in the units window. The moving of the carriage has thus brought opposite to the master wheel the next wheel to the right. The pushing down of another key, say 7, by the operator causes the master wheel M to introduce a 7 into this second wheel, and the subsequent escapement and moving of the carriage another step to the left brings this 7 into view in the units window, moving the original 8 into the second window, the whole number now visible being 87. And so on. A set of totalizer wheels T is located in alignment with the windows, and the carriage with its wheels is therefore brought into alignment not only with the windows, but also with the totalizer wheels. Further operation depends upon the construction of the machine. But in every ten-key machine where it is not the operator that first determines what decimal place is to be operated in, a traveling carriage is provided for storing up the numbers, which carriage travels toward the left. In Fig. 10 the traveling carriage is represented as provided with a set of wheels which are rotated by a master wheel. This construction is used in the Dudley machine and others. In the Moon-Hopkins and the Dalton, which are more prominently on the market, the traveling carriage does not contain a set of wheels, but employs instead a set of banks of stop pins.

Figure 11 represents the construction of the Moon-Hopkins and the Dalton machines—more particularly the Dalton. There are ten keys, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 which are fulcrumed upon an axis. The back ends of the keys are bent together to form a line, and end in a series of projections, P^0, P^1, P^2, etc. Pushing down the finger piece at the front of the key pushes up the corresponding machines for inserting the number in the totalizer. For each decimal place there is a barrel *B*, part of which, approximately one-third, is covered with teeth which vary in length from a maximum to a minimum, and have the values 9 to 0. Parallel with the axis of the barrel is a square shaft *C*, whereon is slidably mounted a gear *D*, which, by means of a handle *H*, is slid by the operator opposite any desired point. The rotation of the barrel will therefore cause the wheel *D* to be rotated a number of steps, dependent upon the number of teeth on the barrel *B* opposite said wheel. That is, it will be rotated only one step when it is opposite the lower end of the long tooth, and nine steps when it is opposite all of the teeth, as at the upper end. The figure to the left shows a development of the surface of the barrel. The reason why the teeth upon the barrel occupy only about one-third of the circumference is that the other two-thirds is used in the carrying mechanism, which I shall not illustrate at this moment. The above mechanism is the one invented by Leibnitz about 1675 and is now used in the Thomas, the Burkhard, the Tim, the Saxonia, the Archimedes, the Monroe, and many others.

Thomas Machine.

The mechanism in Fig. 14 represents the construction of the Brunsviga machine and its brethren the Thales, the Triumphator, the Marchand, and others. There is a drum *A* capable of being rotated about its axis, and provided in each decimal place with a mechanism like the one before us. In each decimal place there is a rotatable cam provided with a handle *H*, by means of which the operator may rotate it about the axis of the drum *A*. The operator may thus project outside of the circumference of the drum a series of pins *P*, or retract them into the circumference. In Fig. 14 we see that six pins have been projected, whereas three remain below the surface. Mounted upon axes parallel to that of the drum are two totalizer wheels T^1 and T^2, always in mesh with each other, and each provided with ten teeth. It is evident that a rotation given to the drum about its axis will cause the projected teeth or pins *P* to pass by the teeth of T^2 and rotate it an amount dependent upon the number of pins set out. Moreover, this will occur at every revolution of the drum.

Should the drum be rotated in the opposite direction, then the wheels T^1 and T^2 will still be rotated an equal amount, but in the opposite direction, thus accomplishing subtraction instead of addition.

The carrying mechanism of the Brunsviga will now be sketched.

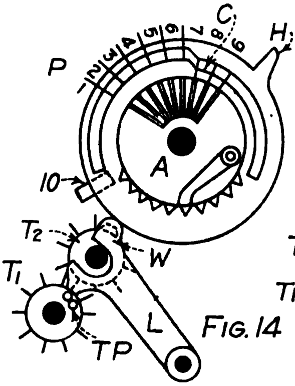


FIG. 14

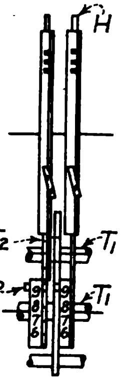


FIG. 15

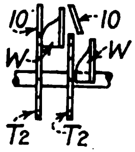
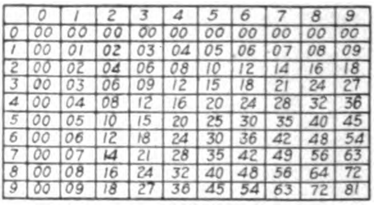


FIG. 16

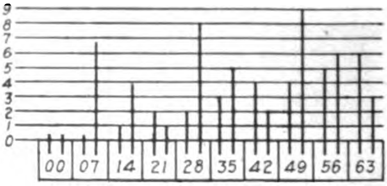
Upon the wheel T^1 is a pin *TP*. Coöperating with the pins is a lever *L* mounted, say, friction-tight upon its fulcrum. It is evident that whenever the pin *TP* passes by the lever, it will push it away from the wheel T^1 upwards toward the drum *A*. The lever *L* carries a peculiar wedge-shaped piece *W* near the drum. Figure 16 shows a view of the wedge taken on a plane including the axes of the drum and the two sets of wheels. Mounted on the drum is a special carrying tooth 10. It is normally held to the right by means of a spring, and in passing will not engage the wheel T^2 to the left. In Fig. 16 are shown two adjacent wheels T^2, two wedges *W*, one to the right and one to the left, and two special carrying teeth 10. The carrying tooth 10 to the right is in its normal position. In passing by the wheel T^2 it would not be interfered with by the wedge *W*. It would therefore miss the wheel T^2. Suppose, however, that previous to the coming around of the carrying tooth 10, the wedge *W* had been pushed in the way of the tooth 10, as is shown by the wedge to the left, the tooth 10 would now strike the wedge immediately before striking the wheel T^2. It would thus be shoved to the left, and in passing by would engage and turn the wheel T^2 one step. It would thus rotate said wheel a special carrying step.

In order that the carrying steps upon the various wheels of the totalizer shall not interfere with each other, these steps are made successive. One is completed before the other commences. To accomplish this the teeth 10 are placed in a spiral around the drum. The spiral always operates units first, tens next, etc. This may require that there shall be a different spiral for subtraction than for addition, and in the Brunsviga, the Monroe, and other machines, this is accomplished by providing two spirals, one of which is effective for addition, and the other one for subtraction.

The above multiplying and dividing machines multiply and divide by repeated addition and subtraction. In multiplying any multiplicand by, say, 7, the multiplicand is rapidly added seven times. Since the highest possible figure is 9 and the lowest is 1, we might say that the average figure is 5, and that these repeated-addition multiplying machines require five steps for multiplying by an average figure. There are, however, multiplying machines which do not operate on the repeated-addition principle. They embody in their mechanism a mechanical representation of the multiplication table.



	0	1	2	3	4	5	6	7	8	9
0	00	00	00	00	00	00	00	00	00	00
1	00	01	02	03	04	05	06	07	08	09
2	00	02	04	06	08	10	12	14	16	18
3	00	03	06	09	12	15	18	21	24	27
4	00	04	08	12	16	20	24	28	32	36
5	00	05	10	15	20	25	30	35	40	45
6	00	06	12	18	24	30	36	42	48	54
7	00	07	14	21	28	35	42	49	56	63
8	00	08	16	24	32	40	48	56	64	72
9	00	09	18	27	36	45	54	63	72	81



Section Through 7

FIG. 17

In Fig. 17 is shown the multiplication table as taught to us in school. Please notice that I have filled out each product until it always contains two figures, one in the tens place, another in the units. Immediately below we see a section of this multiplication table taken through 7, and above that are the products represented mechanically by various lengths of pins, the first pin representing the tens place, and the second pin the units place. For instance, $6 \times 7 = 42$ is represented by a pin in the tens place whose length is 4, and another pin in the units place whose length is 2. The scheme indicated, namely the representation of the multiplication table by different lengths of pins, was the one first proposed as a mechanical representation of the multiplication table, and was brought out by Leon Bollée, a Frenchman, many years ago,—I think in 1896. After him there came many others. The Millionaire machine now on the market, invented by Steiger, works upon practically the same principle, and has almost identically that kind of a multiplication table. He, however, uses only one multiplication table for his whole machine, whereas Bollée used a multiplication table for each decimal place. The Moon-Hopkins machine now on the market, about the fastest multiplying machine with which I am familiar (with the possible exception of the Electric Millionaire), also depends upon that principle; so does the McCaskey, the Cluley, and I suppose many others. Kindly notice that in a multiplication-table multiplying machine it is necessary to perform two additions for each decimal place, namely, the addition of the figures in the tens place and the addition of the figures in the units place. This would seem to indicate that the multiplication-table multiplying machine requiring only two additions per decimal place is about two and a half times as fast as the repeated-addition multiplying machines, which require five additions on the average for each decimal place. In practice, however, the difference is considerably reduced by the special mechanism that must be operated in the multiplication-table multiplying machines, and which do not occur in the repeated-addition multiplying machines.

The above refers to the multiplication of a multiplicand by a multiplier of a single figure, say, 4896 by 7. In case the multiplier has more than one figure, it is necessary to move some portion of the mechanism relatively to another to thereby shift the decimal place. This is accomplished on most machines by hand, but on the Moon-Hopkins and Millionaire machines it is accomplished automatically.

DIVIDING MACHINES.

Division is ordinarily accomplished mentally by guessing at a trial divisor, attempting the division, seeing whether it is right or wrong, and correcting the result in accordance therewith. This guessing process has not been followed mechanically; in the machines that divide, division is accomplished by continuous subtraction of the divisor and the determination when that divisor has been subtracted a sufficient number of times. In the machines on the market this determination occurs whenever the remainder obtained by the continuous subtraction of the divisor from the dividend becomes negative. That is, it occurs just one step too late. This necessitates one retracing step to correct the error just introduced. The machines therefore operate as follows:

Subtract, subtract continually until the remainder becomes negative. This is now one step too far. Therefore add once to correct this last wrong subtraction and then step down one decimal place, and repeat the process.

In some machines on the market the operator has to watch to see when the remainder will become negative. In others, namely, the Millionaire, the Brunsviga, the Thales, the Marchand, etc., an audible signal is given by ringing a bell whenever the remainder becomes negative.

You will therefore notice that only a reversible multiplying machine can be readily used as a dividing machine. Those which are not reversible, like the Ensign, are able to accomplish division, but nowhere nearly as conveniently as those which are reversible, like the Brunsviga.

The crowning attempt along this line has been made by Rechnitzer, of Vienna, who has actually constructed a machine wherein all that was necessary was for the operator to insert the dividend, say of twenty figures, and a divisor, say of ten figures, pull the handle, and wait until the machine automatically ground out the quotient and the remainder. He attempted to put it on the market, but I have not yet seen it. Its arrival would be welcome, as it would be a great convenience.

REACTIONS IN A THREE-LEGGED STIFF FRAME WITH HINGED COLUMN BASES

N. M. Stineman, Assoc. W. S. E.

Presented September 14, 1914

In the treatment of stiff frames which are acted upon by horizontal forces, such as wind or traction, it is the usual practice in text-books to assume that the horizontal reactions at the column bases are equal to each other, their sum being equal to the total horizontal force, and that the vertical reactions are proportional to the distance from the centre of gravity of the columns.

Consider the frame in Fig. 1, acted upon by the horizontal force P. The columns are hinged at the base, are equal in length, and the spans are equal. This structure, being without lateral bracing, is statically-indeterminate; but by making the assumptions referred to above, it is possible to obtain certain formulas for the horizontal and vertical reactions. Without going into the reasoning which leads to those formulas, they are here given. (See Ketchum's "Steel Mill Buildings," 1910 edition, p. 119):

$$H_1 = H_2 = H_3 = \tfrac{1}{3}P; \; V_1 = -V_3 = \frac{Pl}{2s}; \text{ and } V_2 = 0$$

However, these formulas are correct only when the legs have equal cross-sections (i. e., equal moments of inertia) and the top cross-girder is absolutely rigid. To assume that the top girder is absolutely rigid is equivalent to assuming that its moment of inertia is practically equal to infinity. This may be true in some classes of steel structures, such as the one mentioned in the reference noted above; but in other classes of steel structures and in reinforced concrete frames, in which the moment of inertia of the top girder is but several times as large as that of the columns, it will be shown in this article that while the foregoing formulas are fairly accurate for certain very special cases, there is a real danger in trying to fit them to more general cases. Suppose the frame were to contain several variations from the conditions assumed in Fig. 1, such as unequal spans, unequal column lengths, or columns with unequal moments of inertia. It will be shown that under such general conditions the above formulas would give results entirely wrong, and that a designer should not assume that they will solve his general problem merely because they do solve a special one.

Let us assume, first, that the frame in Fig. 1 has columns with equal lengths and cross-sections, but that the top girder, instead of being rigid, has a moment of inertia equal to twice that of the columns. The conditions may then be stated as follows:

November, 1914

I = *moment of inertia of each column*
$2I$ = *moment of inertia of the cross-girder*
$l = 40$ *ft.*
$s = 20$ ft.
$P = 120{,}000$ *lbs.*

Solving the reactions by the usual method, the result is—

$H_1 = 40{,}000$ *lbs.*; $H_2 = 40{,}000$ *lbs.*; $H_3 = 40{,}000$ *lbs.*;
$V_1 = 120{,}000$ *lbs.*; $V_2 = 0$; *and* $V_3 = -120{,}000$ *lbs.*

The true values, determined from formulas to be derived in the following pages by the Principle of Least Work, are found to be—

$H_1 = 38{,}000$ *lbs.*; $H_2 = 44{,}000$ *lbs.*; $H_3 = 38{,}000$ *lbs.*;
$V_1 = 120{,}000$ *lbs.*; $V_2 = 0$; *and* $V_3 = -120{,}000$ *lbs.*

If the spans were greater in proportion to the column lengths, the variation would be correspondingly greater. For example, if the spans were 20 ft. and the column lengths were 20 ft., the reactions would be—

$H_1 = 36{,}670$ *lbs.*; $H_2 = 46{,}660$ *lbs.*; $H_3 = 36{,}670$ *lbs.*;
$V_1 = 120{,}000$ *lbs.*; $V_2 = 0$; *and* $V_3 = -120{,}000$ *lbs.*

It is evident that the assumptions usually made give results which are approximately accurate for the very special case in Fig. 1. But as stated before, the real danger lies in the attempt to fit the formulas for the special case to more general conditions. Suppose the frame in Fig. 1 were a reinforced concrete bridge abutment or approach, and that the column *DE*, supporting the bridge seat, were much larger than the others. The following conditions may be taken as typical:

I = *moment of inertia of columns BA and CF.*
$6I$ = *moment of inertia of column DE.*
$5.4I$ = *moment of inertia of cross-girder.*
l, s, *and* P, *have the same values as before*

The true values of the reactions, computed by formulas to be derived later, will now be—

$H_1 = 17{,}885$ *lbs.*; $H_2 = 21{,}100$ *lbs.*; $H_3 = 81{,}015$ *lbs.*;
$V_1 = 25{,}310$ *lbs.*; $V_2 = 189{,}380$ *lbs.*; $V_3 = -214{,}690$ *lbs.*

This shows a variation from the results obtained by the usual method which is too great to be disregarded. In fact, there has been a complete readjustment in the relation between the reactions, merely because one of the columns has been enlarged in cross-section. If the spans were made unequal and the column lengths were made unequal, a still greater variation would be expected.

THE PRINCIPLE OF LEAST WORK

A well-known law of mechanics, called Hooke's Law, states that when a body is acted upon by an external force, the former undergoes a deformation, and that the deformation is proportional to the force so long as the material is not stressed beyond the elastic limit. It is supposed that the deformation disappears when the force is removed, the body returning to its original state.

The energy stored up in the body while it is being acted upon is called the work of resistance. This work of resistance will hereafter be denoted by ω.

It can be shown by mathematical reasoning that the work of resistance will be the least that is necessary to maintain equilibrium in the structure; and therefore the principle which has been evolved from such reasoning has been called the Principle of Least Work. The fundamental basis underlying the Principle of Least Work may best be given in the Theorems of Castigliano, stated by him in his *Theorie des Gleichgewichtes Elastisches System.* These theorems are:

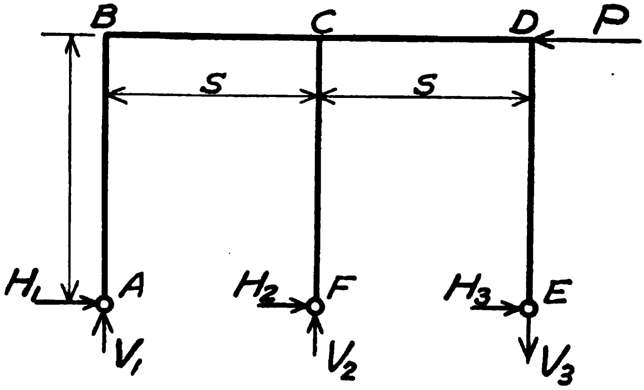


FIG. 1

1. The displacement of the point of application of an external force acting on a body—caused by the elastic deformation of the latter—is equal to the first derivative of the work of resistance performed in the body, with respect to the force.
2. The partial derivatives of the work of resistance with respect to statically-indeterminate forces which are so chosen that the forces themselves perform no work are equal to zero.

The second theorem is in reality a special case of the first, in which the external forces themselves do not undergo any displacement. Inasmuch as work is defined as force times displacement, the external forces will in this case perform no work.

EQUATION OF WORK OF RESISTANCE

When any elastic body is deformed by an external bending moment, it is possible to write an equation of the work of resistance in terms of the bending moment. Omitting the mathematical reduction, which is given in *Statically-Indeterminate Stresses*, by Isami Hiroi, Dr. Eng., the value of the work of resistance in any member of length l is—

$$\omega=\int_0^l \frac{M^2dx}{2EI} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Other equations may be written for the work of resistance due to direct stress, shear, and normal stress; but these will not be required in the following solution.

ANALYSIS OF A THREE-LEGGED STIFF FRAME WITH HINGED COLUMN BASES, STRESSED BY A HORIZONTAL LOAD

The Principle of Least Work will now be applied to the solution of the reactions—and consequently the moments, shears, and direct stresses—in a three-legged stiff frame acted upon by a horizontal force P, as shown in Fig. 2. It will be seen upon referring to Fig. 2 that this is a general case in which the columns have unequal lengths and unequal moments of inertia, and that the spans have unequal lengths. It is assumed that the top cross-girder will have the same moment of inertia I_4 over each span, for structural reasons.

Formulas will be derived for this general case, after which they will be modified to cover various special cases.

The following notation refers to Fig. 2:

l_1, l_2, and l_3=length of columns BA, CF, and DE, respectively.
s_1 and s_2=span lengths.
I_1, I_2, and I_3=moments of inertia of columns.
I_4=moment of inertia of cross-girder.
P=a horizontal force applied at the neutral axis of the cross-girder.
H_1, H_2, and H_3=horizontal reactions due to P.
V_1, V_2, and V_3=vertical reactions due to P.
M_1, M_2, and M_3=moments at top of columns, due to the force P.
M_{I}, M_{II}, M_{III}, M_{IV}, and M_{V}=moments at any point in parts BA, CF, DE, BC, and CD, respectively, due to the force P.

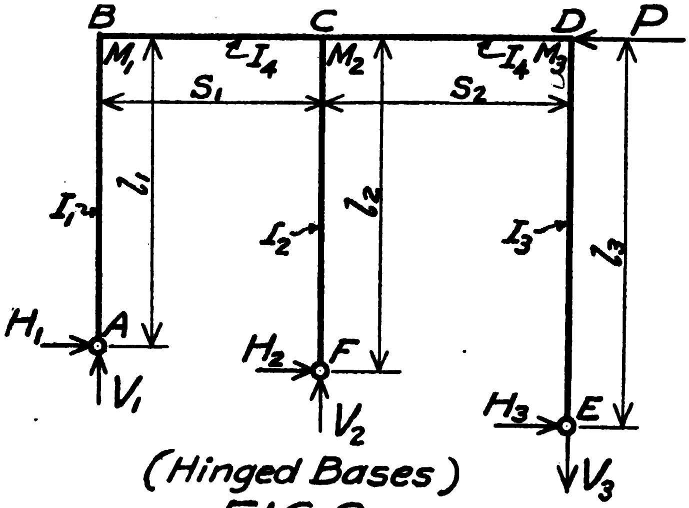
The structure in Fig. 2 contains six unknowns, H_1, H_2, H_3, V_1, V_2, and V_3.

The moments M_1, M_2, and M_3, are equal, respectively, to $-H_1l_1$, $\pm H_2l_2$, and H_3l_3. Moments causing compression in the outside fibre of the structure are considered positive.

Three unknowns, say V_2, V_3, and H_3, may be expressed in terms of the remaining unknowns, V_1, H_1, and H_2, by the three conditions of static equilibrium.

Then V_1, H_1, and H_2, are to be found by the Principle of Least Work.

From the three conditions of static equilibrium—namely, that the summation of horizontal forces equals zero, the summation of vertical forces equals zero, and the summation of moments about any point equals zero—



(Hinged Bases)
FIG. 2

$$V_1+V_2-V_3=0 \quad \ldots\ldots (2)$$
$$H_1+H_2+H_3=P \quad \ldots\ldots (3)$$
$$V_1\,s_1+V_3\,s_2-H_1\,l_1-H_2\,l_2-H_3\,l_3=0 \quad \ldots\ldots (4)$$

Equation (4) has been obtained by taking moments about C Fig. 2.

$$V_2=(V_3-V_1) \qquad \textit{from } (2) \ldots\ldots (5)$$
$$H_3=P-H_1-H_2 \qquad \textit{from } (3) \ldots\ldots (6)$$
$$V_3=\frac{H_1l_1+H_2l_2+H_3l_3-V_1s_1}{s_2} \quad \textit{from } (4) \ldots\ldots (7)$$

The moment anywhere in column BA is—
$M_{\mathrm{I}} = -H_1 x$, *x measured from A.*
The moment in column CF is—
$M_{\mathrm{II}} = \pm H_2 x$, *x measured from F.*
The moment in column DE is—
$M_{\mathrm{III}} = H_3 x$, *x measured from E.*
The moment in the girder BC is—
$M_{\mathrm{IV}} = -H_1 l_1 + V_1 x$, *x measured from B.*
The moment in the girder CD is—
$M_{\mathrm{V}} = H_3 l_3 - V_3 x$, *x measured from D.*

Neglecting the deformation due to shear and direct stress, which is small in comparison with the deformation due to bending moment, the total internal work of resistance is, from Eq. (1),—

$$\omega = \int_0^{l_1} \frac{M^2_{\mathrm{I}}dx}{2I_1E} + \int_0^{l_2} \frac{M^2_{\mathrm{II}}dx}{2I_2E} + \int_0^{l_3} \frac{M^2_{\mathrm{III}}dx}{2I_3E} + \int_0^{s_1} \frac{M^2_{\mathrm{IV}}dx}{2I_4E} + \int_0^{s_2} \frac{M^2_{\mathrm{V}}dx}{2I_4E}$$

Substituting the above values of the moments M_{I} to M_{V}—

$$\omega = \int_0^{l_1} \frac{(-H_1x)^2dx}{2I_1E} + \int_0^{l_2} \frac{(\pm H_2x)^2dx}{2I_2E} + \int_0^{l_3} \frac{(H_3x)^2dx}{2I_3E}$$
$$+ \int_0^{s_1} \frac{(-H_1l_1+V_1x)^2dx}{2I_4E} + \int_0^{s_2} \frac{(H_3l_3-V_3x)^2dx}{2I_4E}$$

Integrating the foregoing equation between the limits indicated—

$$\omega = \frac{H_1^2l_1^3}{6I_1E} + \frac{H_2^2l_2^3}{6I_2E} + \frac{H_3^2l_3^3}{6I_3E} + \frac{H_1^2l_1^2s_1}{2I_4E} - \frac{H_1l_1V_1s_1^2}{2I_4E} + \frac{V_1^2s_1^3}{6I_4E} + \frac{H_3^2l_3^2s_2}{2I_4E}$$
$$- \frac{H_3l_3V_3s_2^2}{2I_4E} + \frac{V_3^2s_2^3}{6I_4E}$$

But $H_3 = P - H_1 - H_2$, and $V_3 = \dfrac{H_1l_1 + H_2l_2 + (P - H_1 - H_2)l_3 - V_1s_1}{s_2}$

By substituting these values of H_3 and V_3, an equation is obtained which contains no unknowns other than H_1, H_2, and V_1. The equation is—

$$\omega = \frac{H_1^2l_1^3}{6I_1E} + \frac{H_2^2l_2^3}{6I_2E} + \frac{(P-H_1-H_2)^2l_3^3}{6I_3E} + \frac{H_1^2l_1^2s_1}{2I_4E} - \frac{H_1l_1V_1s_1^2}{2I_4E} + \frac{V_1^2s_1^3}{6I_4E}$$
$$+ \frac{(P-H_1-H_2)^2l_3^2s_2}{2I_4E} - \frac{(P-H_1-H_2)l_3[H_1l_1+H_2l_2+(P-H_1-H_2)l_3-V_1s_1]s_2}{2I_4E}$$
$$+ \frac{[H_1l_1+H_2l_2+(P-H_1-H_2)l_3-V_1s_1]^2s_2}{6I_4E}$$

Expanding this equation, the result is—

$$\omega=\frac{H_1^2l_1^3}{6I_1E}+\frac{H_2^2l_2^3}{6I_2E}+\frac{P^2l_3^3+H_1^2l_3^3+H_2^2l_3^3-2PH_1l_3^3-2PH_2l_3^3+2H_1H_2l_3^3}{6I_3E}$$

$$+\frac{H_1^2l_1^2s_1}{2I_4E}-\frac{H_1l_1V_1s_1^2}{2I_4E}+\frac{V_1^2s_1^3}{6I_4E}+\frac{P^2l_3^2s_2+H_1^2l_3^2s_2+H_2^2l_3^2s_2-2PH_1l_3^2s_2}{2I_4E}$$

$$+\frac{-2PH_2l_3^2s_2+2H_1H_2l_3^2s_2-PH_1l_1l_3s_2-PH_2l_2l_3s_2-P^2l_3^2s_2+2PH_1l_3^2s_2}{2I_4E}$$

$$+\frac{2PH_2l_3^2s_2+PV_1l_3s_1s_2+H_1^2l_1l_3s_2+H_1H_2l_2l_3s_2-H_1^2l_3^2s_2-2H_1H_2l_3^2s_2}{2I_4E}$$

$$+\frac{-H_1V_1l_3s_1s_2+H_1H_2l_1l_3s_2+H_2^2l_2l_3s_2-H_2^2l_3^2s_2-H_2V_1l_3s_1s_2}{2I_4E}+\frac{H_2^2l_3^2s_2}{6I_4E}$$

$$+\frac{H_1^2l_1^2s_2+H_2^2l_2^2s_2+P^2l_3^2s_2+H_1^2l_3^2s_2+V_1^2s_1^2s_2+2H_1H_2l_1l_2s_2+2PH_1l_1l_3s_2}{6I_4E}$$

$$+\frac{-2H_1^2l_1l_3s_2-2H_1H_2l_1l_3s_2-2H_1V_1l_1s_1s_2+2PH_2l_2l_3s_2-2H_1H_2l_2l_3s_2}{6I_4E}$$

$$+\frac{-2H_2^2l_2l_3s_2-2H_2V_1l_2s_1s_2-2PH_1l_3^2s_2-2PH_2l_3^2s_2-2PV_1l_3s_1s_2+2H_1H_2l_3^2s_2}{6I_4E}$$

$$+\frac{2H_1V_1l_3s_1s_2+2H_2V_1l_3s_1s_2}{6I_4E}$$

After like terms are combined in the foregoing equation, the expression becomes—

$$\omega=\frac{H_1^2l_1^3}{6I_1E}+\frac{H_2^2l_2^3}{6I_2E}+\frac{P^2l_3^3+H_1^2l_3^3+H_2^2l_3^3-2PH_1l_3^3-2PH_2l_3^3+2H_1H_2l_3^3}{6I_3E}$$

$$+\frac{H_1^2l_1^2s_1-H_1l_1V_1s_1^2}{2I_4E}+\frac{V_1^2s_1^3+P^2l_3^2s_2+H_1^2l_3^2s_2+H_2^2l_3^2s_2-2PH_1l_3^2s_2}{6I_4E}$$

$$+\frac{-2PH_2l_3^2s_2+2H_1H_2l_3^2s_2-PH_1l_1l_3s_2-PH_2l_2l_3s_2+PV_1l_3s_1s_2+H_1^2l_1l_3s_2}{6I_4E}$$

$$+\frac{H_1H_2l_2l_3s_2-H_1V_1l_3s_1s_2-H_2V_1l_3s_1s_2+H_1H_2l_1l_3s_2+H_2^2l_2l_3s_2+H_1^2l_1^2s_2}{6I_4E}$$

$$+\frac{H_2^2l_2^2s_2+V_1^2s_1^2s_2+2H_1H_2l_1l_2s_2-2H_1V_1l_1s_1s_2-2H_2V_1l_2s_1s_2}{6I_4E}$$

From the first Theorem of Castigliano, it is seen that if the foregoing equation be differentiated successively with respect to the forces H_1, H_2, and V_1, the expressions so obtained will represent the displacement of the points of application of these forces. But since the points of application of the forces H_1, H_2, and V_1, do not move, each of the derivatives will be placed equal to zero, as stated in the second Theorem.

Differentiating with respect to H_1—

$$\frac{d\omega}{dH_1}=\frac{H_1l_1^3}{3I_1E}+\frac{H_1l_3^3}{3I_3E}-\frac{Pl_3^3}{3I_3E}+\frac{H_2l_3^3}{3I_3E}+\frac{H_1l_1^2s_1}{I_4E}-\frac{l_1V_1s_1^2}{2I_4E}+\frac{H_1l_3^2s_2}{3I_4E}-\frac{Pl_3^2s_2}{3I_4E}$$

$$+\frac{H_2l_3^2s_2}{3I_4E}-\frac{Pl_1l_3s_2}{6I_4E}+\frac{H_1l_1l_3s_2}{3I_4E}+\frac{H_2l_2l_3s_2}{6I_4E}-\frac{V_1l_3s_1s_2}{6I_4E}+\frac{H_2l_1l_3s_2}{6I_4E}+\frac{H_1l_1^2s_2}{3I_4E}$$

$$+\frac{H_2l_1l_2s_2}{3I_4E}-\frac{V_1l_1s_1s_2}{3I_4E}=0\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Differentiating with respect to H_2—

$$\frac{d\omega}{dH_2}=\frac{H_2l_2^3}{3I_2E}+\frac{H_2l_3^3}{3I_3E}-\frac{Pl_3^3}{3I_3E}+\frac{H_1l_3^3}{3I_3E}+\frac{H_2l_3^2s_2}{3I_4E}-\frac{Pl_3^2s_2}{3I_4E}+\frac{H_1l_3^2s_2}{3I_4E}-\frac{Pl_2l_3s_2}{6I_4E}$$

$$+\frac{H_1l_2l_3s_2}{6I_4E}-\frac{V_1l_3s_1s_2}{6I_4E}+\frac{H_1l_1l_3s_2}{6I_4E}+\frac{H_2l_2l_3s_2}{3I_4E}+\frac{H_2l_2^2s_2}{3I_4E}+\frac{H_1l_1l_2s_2}{3I_4E}-\frac{V_1l_2s_1s_2}{3I_4E}=0$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Differentiating with respect to V_1—

$$\frac{d\omega}{dV_1}=-\frac{H_1l_1s_1^2}{2I_4E}+\frac{V_1s_1^3}{3I_4E}+\frac{Pl_3s_1s_2}{6I_4E}-\frac{H_1l_3s_1s_2}{6I_4E}-\frac{H_2l_3s_1s_2}{6I_4E}+\frac{V_1s_1^2s_2}{3I_4E}-\frac{H_1l_1s_1s_2}{3I_4E}$$

$$-\frac{H_2l_2s_1s_2}{3I_4E}=0\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

After each of the preceding equations is multiplied by $6I_4E$, and other reductions are made, they take the following final form:

$$H_1\left[2l_1\left(\frac{l_1^2I_4}{s_2I_1}+3l_1\frac{s_1}{s_2}+l_1+l_3\right)+2l_3\left(\frac{l_3^2I_4}{s_2I_3}+l_3\right)\right]$$

$$+H_2\left[l_3\left(\frac{2l_3^2I_4}{s_2I_3}+l_1+l_2+2l_3\right)+2l_1l_2\right]$$

$$-V_1\left[s_1\left(3l_1\frac{s_1}{s_2}+2l_1+l_3\right)\right]-Pl_3\left(\frac{2l_3^2I_4}{s_2I_3}+l_1+2l_3\right)=0\ldots\ldots\ldots\ldots(11)$$

$$H_1\left[l_3\left(\frac{2l_3^2I_4}{s_2I_3}+l_1+l_2+2l_3\right)+2l_1l_2\right]$$

$$+H_2\left[2l_2\left(\frac{l_2^2I_4}{s_2I_2}+l_2+l_3\right)+2l_3\left(\frac{l_3^2I_4}{s_2I_3}+l_3\right)\right]$$

$$-V_1\left[s_1(2l_2+l_3)\right]-Pl_3\left(\frac{2l_3^2I_4}{s_2I_3}+l_2+2l_3\right)=0\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

$$H_1\left[3l_1\frac{s_1}{s_2}+2l_1+l_3\right]+H_2\left[2l_2+l_3\right]-V_1\left[2s_1\left(\frac{s_1}{s_2}+1\right)\right]-Pl_3=0\ldots\ldots(13)$$

Equations (11), (12), and (13), are simultaneous equations, and all that remains to be done is to substitute the proper values of the column lengths, span lengths, and moments of inertia, after which the reactions H_1, H_2, and V_1, may be found for any general case such as is shown in Fig. 2.

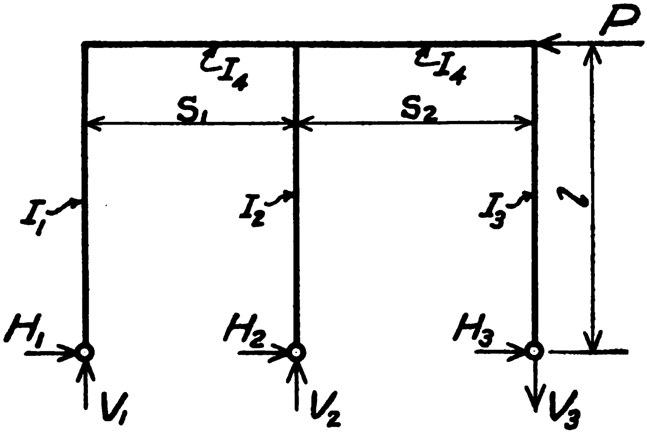


FIG. 3

If the stiff frame is made of reinforced concrete, it is not likely that the exact amount of steel is known at this time, so that the exact moments of inertia can not be obtained. However, since the moments of inertia invariably appear as ratios, it will be sufficiently close to use the moments of inertia of the rectangular sections, disregarding that of the steel.

The remaining reactions, H_3, V_3, and V_2, may now be found from equations (5), (6), and (7). For convenience, the formulas will be repeated here. Thus:

$$H_3=P-H_1-H_2\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(14)$$

$$V_3=\frac{H_1l_1+H_2l_2+H_3l_3-V_1s_1}{s_2}\ldots\ldots\ldots\ldots\ldots\ldots(15)$$

$$V_2=(V_3-V_1)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(16)$$

In solving for V_2, proper attention must be paid to the algebraic signs of V_1 and V_3.

November, 1914

If the value of any force comes out with a negative sign, its direction is opposite to that assumed in the figures.

SPECIAL CASES

Various special cases will now be considered. It will be seen that the general formulas become greatly simplified as the structure approaches the conditions assumed in Fig. 1.

CASE I.—For legs having equal lengths (but unequal moments of inertia), the spans remaining unequal Eqs. (11), (12), and (13), reduce to the following:

$$H_1\left[2l\left(\frac{I_4}{I_1}+\frac{I_4}{I_3}\right)+6(s_1+s_2)\right]+H_2\left[2l\frac{I_4}{I_3}+6s_2\right]-V_1\left[3\frac{s_1}{l}(s_1+s_2)\right]$$
$$-P\left(2l\frac{I_4}{I_3}+3s_2\right)=0 \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(17)$$

$$H_1\left[2l\frac{I_4}{I_3}+6s_2\right]+H_2\left[2l\left(\frac{I_4}{I_2}+\frac{I_4}{I_3}\right)+6s_2\right]-V_1\left[\frac{3s_1s_2}{l}\right]$$
$$-P\left(2l\frac{I_4}{I_3}+3s_2\right)=0 \quad\ldots\ldots\ldots\ldots\ldots\ldots(18)$$

$$H_1\left[3(s_1+s_2)\right]+H_2\left[3s_2\right]-V_1\left[2\frac{s_1}{l}(s_1+s_2)\right]-Ps_2=0 \quad\ldots\ldots(19)$$

CASE II.—For equal spans, the legs remaining unequal, equations (11), (12), and (13), reduce to the following:

$$H_1\left[2l_1\left(\frac{l_1^2I_4}{sI_1}+4l_1+l_3\right)+2l_3\left(\frac{l_3^2I_4}{sI_3}+l_3\right)\right]$$
$$+H_2\left[l_3\left(\frac{2l_3^2I_4}{sI_3}+l_1+l_2+2l_3\right)+2l_1l_2\right]$$
$$-V_1\left[s(5l_1+l_3)\right]-Pl_3\left(\frac{2l_3^2I_4}{sI_3}+l_1+2l_3\right)=0 \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots(20)$$

$$H_1\left[l_3\left(\frac{2l_3^2I_4}{sI_3}+l_1+l_2+2l_3\right)+2l_1l_2\right]$$
$$+H_2\left[2l_2\left(\frac{l_2^2I_4}{sI_2}+l_2+l_3\right)+2l_3\left(\frac{l_3^2I_4}{sI_3}+l_3\right)\right]$$
$$-V_1\left[s(2l_2+l_3)\right]-Pl_3\left(\frac{2l_3^2I_4}{sI_3}+l_2+2l_3\right)=0 \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots(21)$$

$$H_1\left[5l_1+l_3\right]+H_2\left[2l_2+l_3\right]-V_1\left[4s\right]-Pl_3=0\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,(22)$$

CASE III.—For legs having equal lengths, but uneqal moments for inertia, the spans also being equal, the Eqs. (11), (12), and (13), reduce to the following:

$$H_1\left[2l\left(\frac{I_4}{I_1}+\frac{I_4}{I_3}\right)+12s\right]+H_2\left[2l\frac{I_4}{I_3}+6s\right]-V_1\left[6\frac{s^2}{l}\right]$$
$$-P\left(2l\frac{I_4}{I_3}+3s\right)=0\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,(23)$$

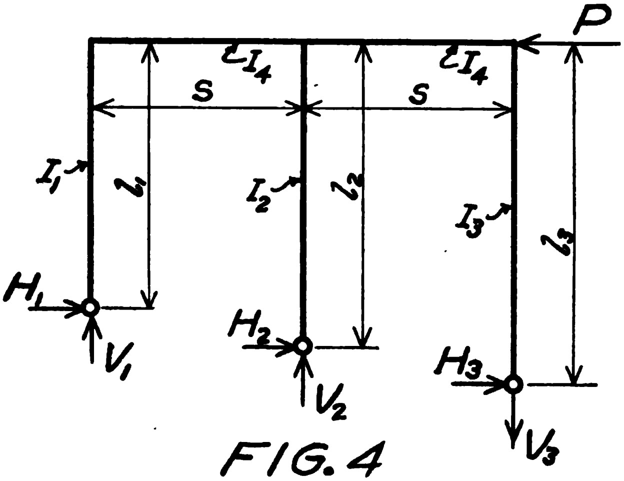


FIG. 4

$$H_1\left[2l\frac{I_4}{I_3}+6s\right]+H_2\left[2l\left(\frac{I_4}{I_2}+\frac{I_4}{I_3}\right)+6s\right]-V_1\left[3\frac{s^2}{l}\right]$$
$$-P\left(2l\frac{I_4}{I_3}+3s\right)=0\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,(24)$$

$$6H_1+3H_2-4\frac{s}{l}V_1-P=0\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,.\,(25)$$

CASE IV.—When the spans are equal, and the legs have equal lengths and equal moments of inertia I, independent expressions for the reactions may be found. First, Eqs. (11), (12), and (13), take the following form:

$$H_1\left[4l\frac{I_4}{I}+12s\right]+H_2\left[2l\frac{I_4}{I}+6s\right]-V_1\left[6\frac{s^2}{l}\right]-P\left(2l\frac{I_4}{I}+3s\right)=0$$

$$H_1\left[2l\frac{I_4}{I}+6s\right]+H_2\left[4l\frac{I_4}{I}+6s\right]-V_1\left[3\frac{s^2}{l}\right]-P\left(2l\frac{I_4}{I}+3s\right)=0$$

$$6H_1 + 3H_2 - 4\frac{s}{l}V_1 - P = 0$$

Multiplying the second of the foregoing equations by 2 and then subtracting the first equation from it the remainder is—

$$H_2\left[6l\frac{I_4}{I} + 6s\right] - P\left(2l\frac{I_4}{I} + 3s\right) = 0$$

Solving for H_2,—

$$H_2 = \frac{2l + 3s\frac{I}{I_4}}{6l + 6s\frac{I}{I_4}}\cdot P \qquad \text{(26)}$$

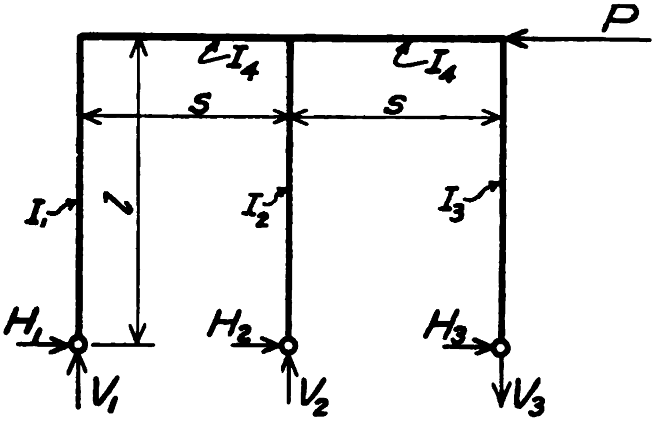


FIG. 5

Multiplying the third of the above equations by $\frac{3}{2}s$ and subtracting it from the first equation, then substituting the value of H_2 from Eq. (26), an expression for H_1 is found which contains no other unknown. Solving for H_1—

$$H_1 = \frac{4l + 3s\frac{I}{I_4}}{12l + 12s\frac{I}{I_4}}\cdot P \qquad \text{(27)}$$

Subtracting the sum of H_1 and H_2 from P, the value of H_3 is—

$$H_3 = \frac{4l + 3s\frac{I}{I_4}}{12l + 12s\frac{I}{I_4}}\cdot P \qquad \text{(28)}$$

From Eqs. (27) and (28), it is seen that under the special conditions of Case IV the horizontal reactions H_1 and H_3 are equal to each other. This would be expected, because of the symmetry of the frame.

Equations (26), (27), and (28), show that as I_4 approaches infinity (the value assigned to I_4 when the cross-girder is assumed to be rigid), the values of H_1, H_2, and H_3, each approach $\frac{1}{3}$P (See Fig. 1). On the other hand, as I_4 approaches zero, the value of H_2 approaches $\frac{1}{2}P$, while the values of H_1 and H_3 each approach $\frac{1}{4}P$. Hence the theoretical range in the value of H_2, when the frame meets the conditions in Fig. 6, is from $\frac{1}{3}P$ to $\frac{1}{2}P$; and for H_1 and H_3 the range is from $\frac{1}{4}P$ to $\frac{1}{3}P$. This character of frame has been discussed in the earlier portion of this article.

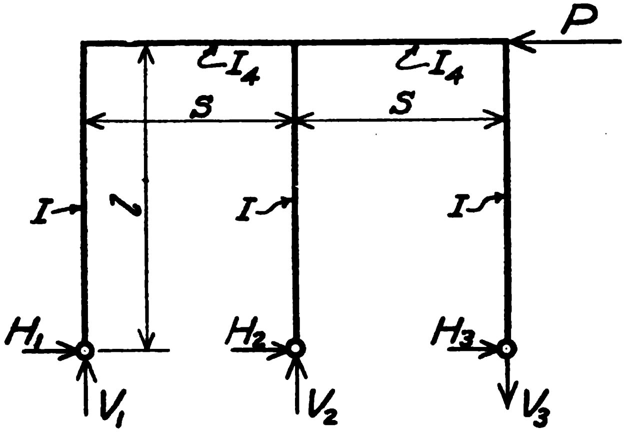


FIG. 6

CASE V.—The cross-girder is assumed to be rigid.

Assuming the cross-girder to be rigid has the effect of making I_4 equal to infinity. The three Eqs. (8), (9), and (10), then take the form—

$$\frac{H_1 l_1^3}{I_1}+\frac{H_1 l_3^3}{I_3}+\frac{H_2 l_3^3}{I_3}-\frac{P l_3^3}{I_3}=0 \quad \text{.........................} (29)$$

$$\frac{H_2 l_2^3}{I_2}+\frac{H_2 l_3^3}{I_3}+\frac{H_1 l_3^3}{I_3}-\frac{P l_3^3}{I_3}=0 \quad \text{.........................} (30)$$

$$0=0 \quad \text{.........................} (31)$$

$$H_1\left(\frac{l_3^3}{I_3}\right)+H_2\left(\frac{l_2^3}{I_2}+\frac{l_3^3}{I_3}\right)=\left(\frac{l_3^3}{I_3}\right) \text{.....} \textit{from } (30)$$

$$H_1\left(\frac{l_1^3}{I_1}+\frac{l_3^3}{I_3}\right)+H_2\left(\frac{l_3^3}{I_3}\right)=P\left(\frac{l_3^3}{I_3}\right)\ldots\ldots \textit{from } (29)$$

$$H_1\left(\frac{l_1^3 I_3}{l_3^3 I_1}+1\right)+H_2=P$$

$$H_1+H_2\left(\frac{l_2^3 I_3}{l_3^3 I_2}+1\right)=P;\ \textit{or }\ H_2=\frac{P-H_1}{\left(\frac{l_2^3 I_3}{l_3^3 I_2}+1\right)},\ \textit{and substituting}$$

$$H_1\left(\frac{l_1^3 I_3}{l_3^3 I_1}+1\right)+\frac{P-H_1}{\left(\frac{l_2^3 I_3}{l_3^3 I_2}+1\right)}=P$$

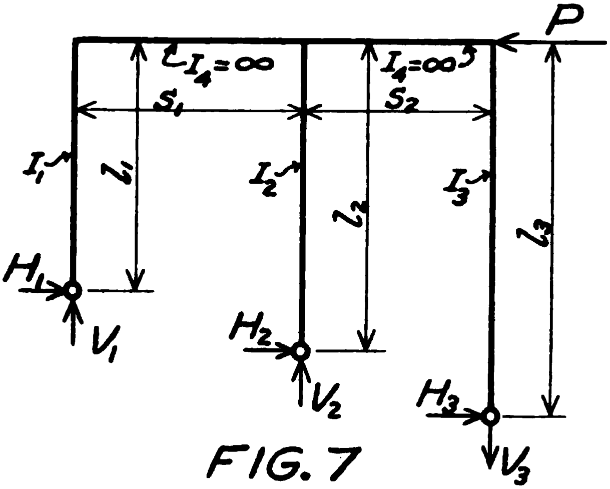


FIG. 7

Finally—

$$H_1=\frac{P}{1+\frac{l_1^3 I_2}{l_2^3 I_1}+\frac{l_1^3 I_3}{l_3^3 I_1}}\ldots\ldots(32)$$

Similarly—

$$H_2=\frac{P}{1+\frac{l_2^3 I_1}{l_1^3 I_2}+\frac{l_2^3 I_3}{l_3^3 I_2}}\ldots\ldots(33)$$

$$H_3=\frac{P}{1+\frac{l_3^3 I_1}{l_1^3 I_3}+\frac{l_3^3 I_2}{l_2^3 I_3}}\ldots\ldots(34)$$

VALUE OF V_1 IN TERMS OF H_1 AND H_2.

It may be desirable in certain cases to know the value of V_1 in terms of H_1 and H_2.

GENERAL EQUATION.—From Eq. (13)

$$V_1 = \frac{H_1\left(3l_1\frac{s_1}{s_2} + 2l_1 + l_3\right) + H_2\left(2l_2 + l_3\right) - Pl_3}{2s_1\left(\frac{s_1}{s_2} + 1\right)} \dots\dots\dots\dots (35)$$

In CASE I the legs have equal lengths l (but unequal moments of inertia), the spans remaining unequal. Eq. (35) then becomes—

$$V_1 = \frac{H_1\left[3\left(\frac{s_1}{s_2} + 1\right)\right] + 3H_2 - P}{2\frac{s_1}{l}\left(\frac{s_1}{s_2} + 1\right)} \dots\dots\dots\dots (36)$$

In CASE II the spans are equal, the legs remaining unequal. Eq. (35) becomes—

$$V_1 = \frac{H_1(5l_1 + l_3) + H_2(2l_2 + l_3) - Pl_3}{4s} \dots\dots\dots\dots (37)$$

In CASE III the spans are equal and the legs have equal lengths, but unequal moments of inertia. Eq. (35) becomes—

$$V_1 = \frac{6H_1 + 3H_2 - P}{4\frac{s}{l}} \dots\dots\dots\dots (38)$$

In CASE IV the spans are equal, the legs are equal and have equal moments of inertia. Eq. (35) becomes—

$$V_1 = \frac{6H_1 + 3H_2 - P}{4\frac{s}{l}} \dots\dots\dots\dots (39)$$

Note:—Equations (38) and (39) have the same form, but not the same value, inasmuch as the values of H_1 and H_2 are different in the two cases.

In CASE V, the upper cross-girder is assumed to be rigid. The expression for V_1 will have the same form as in the GENERAL EQUATION, but the value will be different, inasmuch as the values of H_1 and H_2 will be different. Thus:

$$V_1 = \frac{H_1\left(3l_1\frac{s_1}{s_2} + 2l_1 + l_3\right) + H_2\left(2l_2 + l_3\right) - Pl_3}{2s_1\left(\frac{s_1}{s_2} + 1\right)} \quad \ldots\ldots\ldots\ldots (40)$$

In the very special case where spans are equal, legs are equal and have equal moments of inertia, and the cross-girder is assumed as being rigid, the value of V_1 will be as in Equation (39), except that $H_1 = H_3 = \frac{1}{3} P$, so that the expression is—

$$V_1 = \frac{Pl}{2s} \quad \ldots\ldots\ldots\ldots (41)$$

The value in equation (41) is the value referred to at the beginning of this article, in which it was also assumed that $V_3 = -V_1$ and that $V_2 = 0$.

These last values are correct for the very special conditions named, but as the relations between span lengths and between column lengths are made to vary, the values of the reactions vary rapidly. By way of further illustration, the following is given:

> A three-legged stiff frame has column lengths of $l_1 = 42'.5$, $l_2 = 34'.0$, and $l_3 = 29'.75$; span lengths of $s_1 = s_2 = 17'.0$; moments of inertia of $I_1 = 10\ I$, $I_2 = I_3 = I$, and $I_4 = 8\ I$. The frame is acted upon by a longitudinal traction force of 120,000 lbs. What are the horizontal and vertical reactions at the base of columns, considering the columns hinged at the base?
>
> From equations (20), (21), and (22), the values are, $H_1 = 71{,}500$ lbs., $H_2 = 21{,}000$ lbs., $H_3 = 27{,}500$ lbs., $V_1 = 232{,}500$ lbs., $V_2 = -196{,}000$ lbs., and $V_3 = -36{,}500$ lbs.

The foregoing example further demonstrates the fact that the usual assumptions made for special conditions do not apply at all when conditions become more general.

MOMENTS

The moments in all the parts of the frame may be found from the equations following Eq. (7), after the reactions have been found.

SHEARS

The shears in the columns are equal to the horizontal reactions. The shear in the girder over the left span is equal to V_1. The shear in the girder over the right span is equal to V_3.

DIRECT STRESSES

The direct stress in any column is equal to the vertical reaction on that column.

The direct stress in the girder over the left span is equal to H_1. The direct stress in the girder over the right span is equal to H_1+H_2.

MOMENT AND SHEAR DIAGRAMS

The moments throughout the frame are represented graphically in Fig. 8. Moments causing compression in the outside fibre of the structure are considered positive. The small circles represent points of contraflexure. In some cases, as in the last example, one or both of the top girders will have the same kind of moment over the entire span, so that no point of contraflexure exists in that span. Such a condition is likely to be found either when the corner moment at the top of the adjacent outside column is comparatively large, or when the vertical reaction in the adjacent outside column is comparatively small. Fig. 9 represents roughly the moments in the frame mentioned in that example.

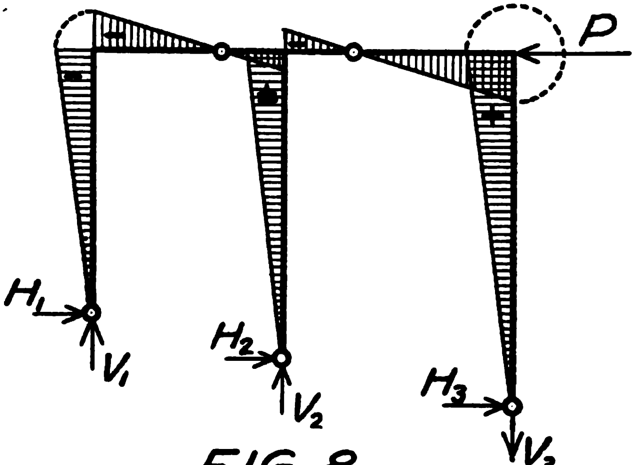


FIG. 8
(Typical Moment Diagram)

The shears in the various members of the structure are represented graphically in Fig. 10. Their actual values are given in a previous paragraph.

COLUMN BASES FIXED OR PARTIALLY FIXED

In the foregoing solution the column bases are considered hinged. It would be possible to derive similar equations for fixed column bases; but since the structure under those conditions would contain nine unknowns, it would be necessary to find six of them by the Principle of Least Work. This would lead to six simultaneous equations, and consequently the formulas would be too long and complicated to be of practical use. Furthermore, it is not probable that the column bases could be fixed on the average foundation material. It should also be remembered that considering the bases hinged has the effect of increasing the bending moment throughout the structure, so that the solution given will be on the safe side.

If for any reason the material of the foundation or the form of the footing is such as to fix, or partially fix, the column bases, then the columns will have points of contraflexure at some distances h_1, h_2, and h_3, above the bases. (See Fig. 11.)

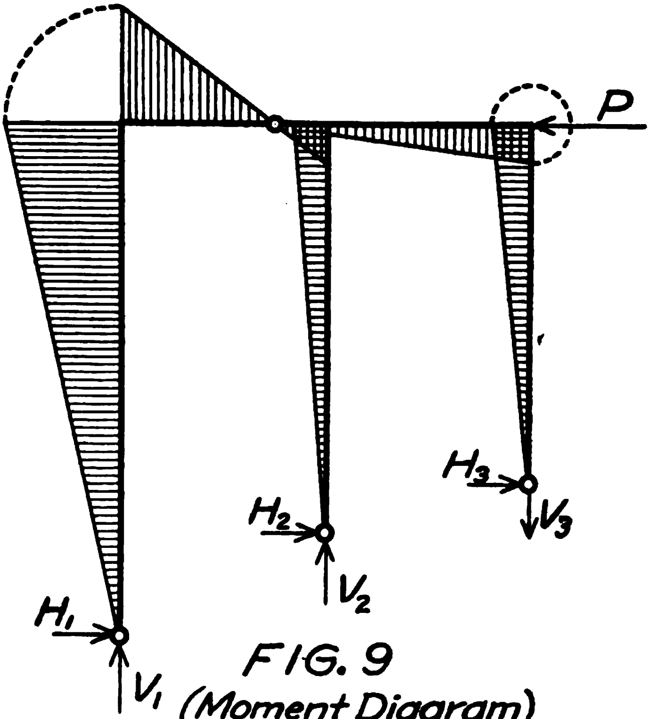


FIG. 9
(Moment Diagram)

Consider any column, as *DE*. If both the top and base of this column were absolutely fixed, or partially fixed to an equal extent, the value of h_3 would be $\frac{1}{2}l_3$. However, for structural reasons the top girder is likely to be quite large, so that the joint at *D* will be more rigid than the base at *E*. This will have the effect of lowering the point of contraflexure, giving a value of h_3 somewhat less than $\frac{1}{2}l_3$.

Because of the uncertainty of the degree of fixity at the base, it will be better to find the moment which the base is capable of taking, after which the point of contraflexure may be found by means of this moment. This is done by first computing the horizontal reactions as though the bases were hinged. The moments in the columns are then found by the equations following Eq. (7), and laid off as shown in the dotted lines, Fig. 11. The moments m_1, m_2, and m_3, which the bases are capable of taking, are now laid off at the column bases, and lines GJ, KL, and QR, are drawn parallel to the dotted lines, and the points of contraflexure are thus located where these lines intersect the column lines. However, *the point of contraflexure should in no case be taken higher than half the column length.* The reactions are now recomputed as before, except that the columns are considered hinged at the points of contraflexure.

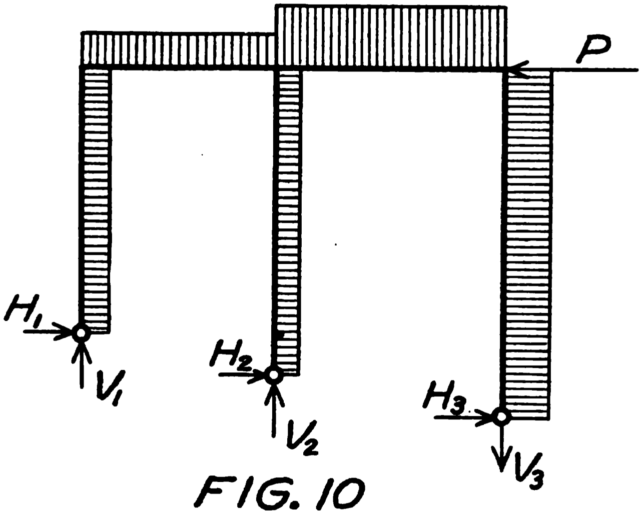


FIG. 10
(Typical Shear Diagram)

The values of the moments m_1, m_2, and m_3, which the bases are capable of taking, are obtained directly from the fundamental formula—

$$M=\frac{pI}{c}$$

Or, if the column footings be rectangular, with a width of b perpendicular to the direction of the force P, and a length d parallel to P, the equation is—

$$M=\frac{pbd^2}{6}$$

If p be expressed in pounds per sq. ft., and b and d in feet, the value of M will be in ft.-lbs.

Suppose now that the base of the column *DE* in Fig. 11 has a width *b* of 6 ft. and a length *d* of 8 ft. The allowable soil pressure is 8,000 lbs. per sq. ft., and the maximum load on the soil from all direct loads amounts to 6,000 lbs. per sq. ft. This leaves a pressure of 2,000 lbs. per sq. ft. which may be taken in flexure—that is, *p* may be 2,000 lbs. per sq. ft. The moment which the base may then take without loading the soil beyond the maximum will be—

$$m_1 = \frac{pbd^2}{6} = \frac{2000 \times 6 \times 64}{6} = 128{,}000 \text{ ft.-lbs.}$$

The maximum pressure on the soil will then be 8,000 lbs. per sq. ft., although on the opposite side of the footing the pressure will be correspondingly reduced to 4,000 lbs. per sq. ft. In case the last named pressure should be reduced to less than zero, the above solution would not hold. It might of course be possible for the base to take a moment greater than 128,000 ft.-lbs.; but the object in view is to make the design consistent throughout, by making the rest of the structure so strong that it will be unnecessary for the base to take more than that amount.

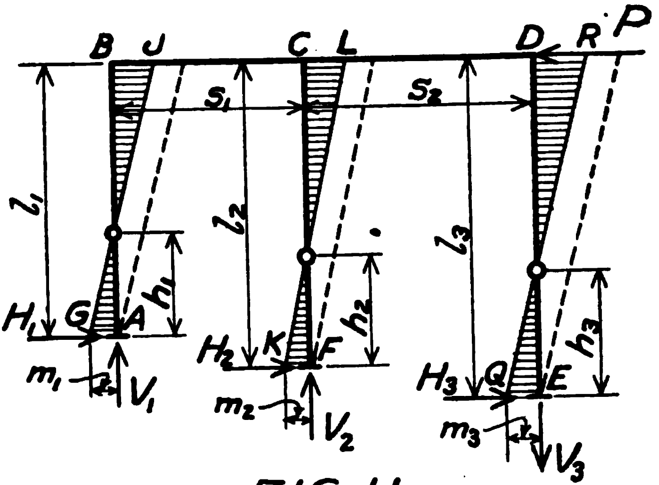


FIG. 11

In general, the column footings should be considered hinged, inasmuch as no actual adhesion exists between the bottom face of the footing and the foundation material. A very slight rocking of the footing would preclude the possibility of its taking any moment, and it should not be considered as doing so unless the footing area is very large or the foundation material is of a very firm character.

PRACTICAL APPLICATION.

The formulas derived in this article may be applied to various classes of three-legged frames or bents having rigid joints and no lateral bracing, the only condition imposed being that the structure shall have the same relative modulus of elasticity throughout. As a matter of fact, if different members of the structure had different moduli of elasticity, these factors could be retained in the equations; but such a condition would hardly occur in practice.

These formulas will perhaps have the most frequent application in the design of reinforced concrete frames. Many designers of this class of structures have found a scarcity of engineering formulas which may be properly applied to the peculiar characteristics of reinforced concrete, since in the majority of cases the published formulas have been developed for use in the design of steel or wooden structures. An example of the possible application of the formulas in this paper may be seen in Fig. 9, which represents one side of a bridge abutment of a type which has in recent years been constructed to some extent by railway companies. Because of the uncertainty of analysis, these abutments have frequently been burdened with an excess of material, although the excess was not necessarily placed where it might do the most good. The economic advantages of such abutments were thoroughly discussed by Mr. Alfred W. Hoffmann in *Railway Engineering and Maintenance of Way,* March, 1914. These advantages will become apparent after a proper study of the conditions. An ordinary retaining wall abutment would have to support the earth fill back of it, and long wing walls would have to be constructed to retain the slope of the fill, all of which would require an enormous amount of material where the abutments are quite high, as they usually are. In consequence, solid abutments would either have to be made very large, or they would have to be placed farther up on the slope, thereby increasing the span and cost of the superstructure.

Nothing has been said thus far in regard to vertical loads, for the reason that approximately correct results may be obtained by designing the top girder as a continuous beam with fixed ends. A more accurate method for the solution of moments due to vertical loads is a graphical method given in *Anwendungen der Graphischen Statik,* third volume, by Dr. W. Ritter. For convenience the outside columns of the frame may be rotated about their tops into a horizontal position and the structure may be designed as a continuous beam of four spans, with the ends either simply supported or partially fixed, accordingly as the column bases are hinged or partially fixed. However, the moments due to vertical loads will in general be far less severe than those due to horizontal loads.

In view of the previously available methods for computing the moments due to vertical loads, this paper will complete the analysis of the Three-legged Stiff Frame. Indebtedness is acknowledged to

Mr. Somers H. Smith, who has checked and criticised a considerable part of this article.

Discussion.

J. J. Richey (Texas Agricultural and Mechanical College). Mr. Stineman's paper, presenting an analysis of the three-legged stiff frame, is a timely discussion of a subject which of late has engaged the attention of a considerable number of engineers. The newer types of reinforced concrete abutments require much more of mathematical analysis than the usual solid abutments, and the difficulty of making the computations has probably stood in the way of their more general adoption.

At first sight the rather formidable looking equations and reductions used by Mr. Stineman in arriving at his general equations for the reactions of the three-legged frame, may tend to frighten the engineer who is not well "up" on his mathematics, but the deduced formulas are not really difficult to use, requiring only the very simple operation of the algebraic solution of three simultaneous equations. The writer had occasion recently to make use of some of these formulas in checking the design of an abutment, and the labor of finding the values of the reactions by their use was a very small part of the total labor involved.

The thoroughness and detail with which the analysis has been made will doubtless be found helpful to those who wish to familiarize themselves with the practical application of the principle of least work. The text-books do not usually devote enough space to the treatment of this subject to make it intelligible to the student, and the principle of least work is, to many, little more than a name and a subject for a joke. Such applications as that given in Mr. Stineman's paper should do much to clear away the haziness with which the average engineer regards this oft-mentioned but little-understood principle.

In the treatment of the frame with legs fixed or partially fixed at the bottom, something further may be said. The author states that "considering the bases hinged has the effect of increasing the bending moment throughout the structure, so that the solution given will be on the safe side." He would except, of course, the lower end of the column, which, with hinged base, would have no moment at the bottom, but with fixed or partially fixed base would have a moment as great or nearly as great at the bottom as at the top.

The proposed method for finding the moment which the base is capable of taking, by the use of the formula $M = \frac{pI}{c}$, as a means of determining the moment at the bottom and the top of the column which is partially fixed at the bottom, is open to some criticism. There can hardly be any assurance that the value for the safe foundation pressure assumed or prescribed will, when used in the formula $M = \frac{pI}{c}$, give any reliable measure of the maximum moment which can occur at the bottom of the column. It will, in general, be rather uncertain what the safe foundation pressure is, and moreover, it is difficult to see just what the term "safe foundation pressure" really means in the present connection. Our knowledge of the action of a soil foundation under unequal pressure over the base of a structure is hardly sufficient to enable us to say that up to a certain pressure the soil will compress so little as to keep the column undeflected or sufficiently so at the base that a certain corresponding moment will be developed in the column, but that at pressures beyond this value the compression of the soil and the deflection of the column increase to such an extent that no greater moment can occur in the column at the base. The point is, then, that the question of what moment can be developed at the base of the column is as much one of judgment or estimation, within limits, as of mathematics. The two extreme conditions may be taken as follows: (1) the column is hinged at the base, and the moment varies from zero at the bottom to a maximum at the top; (2) the bottom and the top are fixed to an equal extent, in which case the moments at these points are each equal to half the maximum value for the other condition. The true condition may be anywhere between these extremes, and it would seem more direct and more consistent to assume at once, without mathematical computation, this intermediate condition, guided, of course, by the information at hand concerning the nature and "safe pressure" of the foundation.

Laying aside the matter discussed in the last paragraph above, in which it appears that mathematical treatment is probably carried a little too far, the solutions presented by Mr. Stineman show conclusively the need for exact analysis of such structures as the three-legged frame. The startling discrepancies between the values obtained by the use of his exact formulas and those found by means of the common assumptions, which are approximately correct only for special cases, show how unsafe it is to depend upon these approximate (?) formulas for this type of structures.

F. E. Vey, ASSOC. W. S. E.: The writer wonders how those specializing in the design of reinforced concrete will view the efforts of Mr. Stineman. He is doubtful if the majority of designers will look upon them in any other way than that they are a mass of mathematical work to be avoided.

It appears that the open-paneled structures (panel without diagonal members) will be one of the chief characteristics of advanced reinforced-concrete design. If this is so, we ought to have some method of finding the stresses in these open panels caused by the action of any loads that may come upon the structure. Without knowing such stresses, we must resort to judgment in the size of sections and the amount and disposition of the steel.

Consider now the method of design which is based almost entirely on judgment. The writer's idea of the method of design by judgment is to have a definite idea of the kind of structure that will work, and from this definite idea to deduce what variations are necessary to produce a structure that will fit the case in hand. The method must be bounded, on the one side by the bitter lessons of failure, and on the other side, by the peculiar faculty of instinct. In the use of this faculty there generally is at the back of the mind a possibility of failure and a necessary lesson to be derived therefrom.

Engineers entrusted with the planning of structures should produce such designs as they *know* will meet the ordinary demands made upon the structures. Their employers expect this and the general public which travels over them has confidence that its safety is assured through the faithful performance of the designer. Anyone who does not strive to the utmost of his powers to attain this ideal of safety should rest content with copying the older classes of design and not striking out in the untried fields of economic reinforced-concrete design.

Every advance is at the cost of a sacrifice, and if one is not willing to make this sacrifice in the form of laborious general investigations and painful attention to details, he should not attempt any advanced step. It seems to the writer that the ultimate, perfected, reinforced-concrete design will be based on a few general principles, which, combined in different ways, give numerous forms of details. To design by instinct and judgment, in place of science, we will meet these combinations and permutations separately, and there are many such combinations in a structure of any size. It seems then that we would have numerous places to fall far short of requisites and we must remember that a structure—as well as a chain—is only as strong as its weakest link, and this weak link may be some (apparently) insignificant detail.

Allowing, for the time being, that an advanced type of structure can be designed primarily by judgment, the next question is—how many of the profession are capable of using this method? It is the writer's opinion that there are very, very few indeed. For the rest of us, we will have to depend upon the method of "two and two are four," that is, the method which has in back of it some science (classified experience and means of sub-dividing or multiplying this experience).

So much for instinct. Now for the part of judgment, that depends upon a general idea of a structure that will work. In the newer departures of reinforced concrete that we are constantly tempted into, how often do we have a definite idea of a structure that will work? The writer ventures to say that very few of us have any confident notion of such a structure when we are dealing with one of these advanced types.

From the foregoing consideration it seems that the method of judgment in the design of advanced types of construction is one that the mass of engineers cannot follow if they are honorably to fulfill their office as designers of trustworthy structures.

We must then find some method of knowing the stresses in these statically indeterminate structures.

The writer, for a considerable time, sought in vain for a bundle of tricks by which he might get at the stresses in these structures and avoid the use of higher mathematics. He was finally forced to adopt this fearful mathematical work, and, much to his surprise, found that it consisted only of such elementary manipulations in calculus as the average student in the subject could pick up with only a few hours review of his college work. The biggest element of the problem was drudgery combined with simple arithmetic accuracy. The rest consisted of ingenuity of arranging and cutting down the work.

Mr. Stineman has presented a trustworthy method of getting at these stresses and if one will study it carefully it will put him in a position to solve this class of construction. The writer has found it most convenient to treat each problem as a special case, that is, put all moments of inertia in terms of one of the inertias, say the smallest, and to put all the lengths in terms of one length. In this way many of the terms that are algebraically independent can be added arithmetically into one term, thus cutting down the length of the equations. However, where a certain type of structure constantly presents itself, it may be well to make an algebraic solution as Mr. Stineman has done.

There are other methods of solving this and similar problems, such as the method of area moments, virtual displacement, and the graphic method of the ellipses of elasticity. However, all these methods involve a considerable amount of work and it seems that it is up to the profession to find some way to reduce this work. This can be done in an indirect way by making the process as mechanical as possible by a skilful system of tabulation for each process. Another indirect method is to lay out the structure so as to have the minimum amount of indeterminateness.

By way of direct methods we might find some graphic process that will be more rapid than the algebraic. Also short cuts might be made if we could throw out of the problem for the time being certain reactions on some members that will only slightly affect the reactions on the members sought. This, however, requires an intimate knowledge of the action of open-paneled structures, but we may expect that this will be the good fortune of some of us in time to come.

Another method that the writer has in mind, which he thinks will be along the lines that this class of structures will be ultimately designed upon, is what he would call the method of successive approximations, that is, cut and try. In this method the structure is cut into two or more simple frames whose properties under unit

$$\frac{1}{EI} \times \left(\begin{array}{c}\text{Area of moment diagram} \\ \text{between those two points}\end{array}\right)$$

The result will be in radians and, as the angle is always very small, the result may be assumed to be the tangent or sine of the angular change.

2. The deflection or displacement of any point A from a tangent to the elastic curve at any other point B is equal to

$$\frac{1}{EI} \times \left(\begin{array}{c}\text{Area of moment diagram} \\ \text{between } A \text{ and } B\end{array}\right) \times$$

(Distance, measured along the beam, from A to the center of gravity of the above moment area.)

E and I are, respectively, the modulus of elasticity and the moment of inertia of the beam.

Space will not be taken here to give the derivation of these rules. Their application to a few simple cases should convince anyone of their trustworthiness.

Figure 1 represents a cantilever beam of length l, with a single load W at its outer end. It is desired to find the deflection d of the point A from a tangent to the elastic curve at B. The area of the moment diagram between A and B is $Wl^2/2$. The moment arm of this area from A is $\frac{2}{3} l$. Applying rule 2;

$$d = \frac{1}{EI} \cdot \frac{Wl^2}{2} \cdot \frac{2}{3} l = \frac{Wl^3}{3EI}$$

Figure 2 shows a simple beam carrying a single load W at its center. The area of the moment diagram between A and B is

$$\frac{Wl}{4} \cdot \left(\frac{1}{2} \cdot \frac{1}{2} l\right) = \frac{Wl^2}{16}$$

The moment arm from A for this area is $\frac{1}{3} l$.

$$d = \frac{1}{EI} \cdot \frac{Wl^2}{16} \cdot \frac{1}{3} l = \frac{Wl^3}{48EI}$$

It will be noted that the deflection of A was obtained from a tangent at the center. The deflection of the point B from a tangent to the curve at A would be an entirely different dimension.

Figure 3(a) shows a load W distributed uniformly along a beam continuous over two equal spans. It is desired to find the proportion of load carried by each of the supports. Suppose the center support omitted and the positive moment diagram drawn for a uniform load on two supports, as shown above the line ABA in figure 3(b). Then apply an upward force R_2 at the center of the beam that will bring the point B back to a level line through the

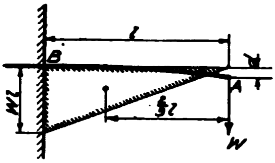


Fig. 1

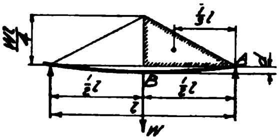


Fig. 2

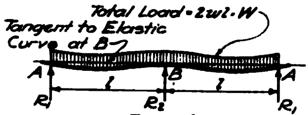


Fig. 3(a)

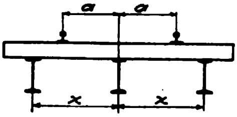


Fig. 4(a)

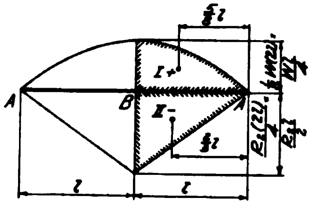


Fig. 3(b)

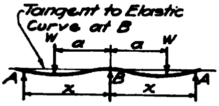


Fig. 4(b)

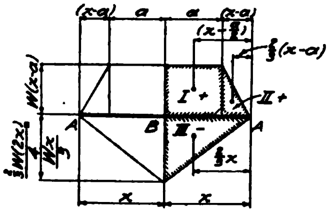


Fig. 4(c)

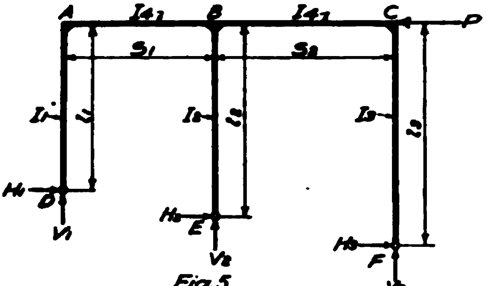


Fig. 5

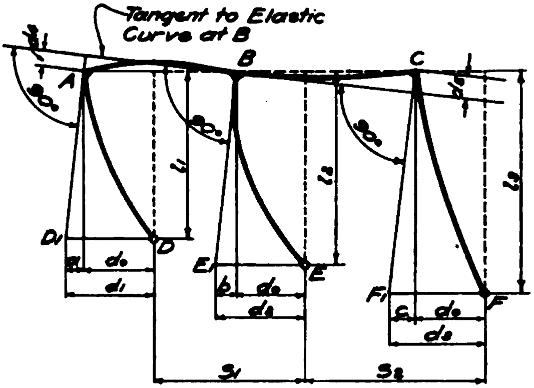


Fig. 6

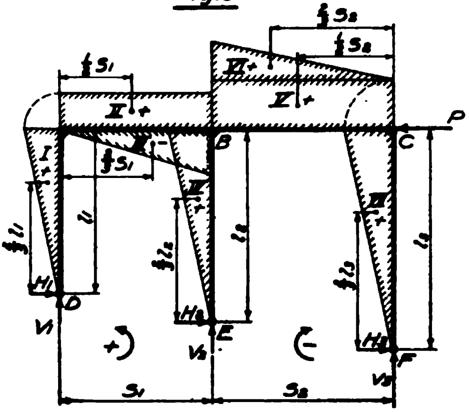


Fig. 7

two end supports. The negative moment diagram for R_2 is shown below the line *ABA*. Placing the reference line tangent to the elastic curve at *B*, it will pass through the two supports *A, A,* for the figure is symmetrical about its center. The deflection or displacement of the point *A* from this tangent is zero. Following are the areas, moment arms, and area moments for that portion of the moment diagram between *A* and *B:*

	Area	Moment arm from *A*	Area Moment
I	$+\frac{Wl}{4}\cdot\frac{2}{3}l=\frac{Wl^2}{6}$	$\frac{5}{8}l$	$+\frac{5Wl^3}{48EI}$
II	$-\frac{R_2l}{2}\cdot\frac{1}{2}l=\frac{R_2l^2}{4}$	$\frac{2}{3}l$	$-\frac{R_2l^3}{6EI}$

$$d=\frac{5Wl^3}{48EI}-\frac{R_2l^3}{6EI}=0$$

$$\frac{R_2}{6}=\frac{5W}{48}$$

$$R_2=\frac{5}{8}W, \qquad R_1=\frac{1}{2}\cdot\frac{3}{8}W=\frac{3}{16}W.$$

In Fig. 4(a) is shown a railroad track supported on three stringers. These stringers should be given such a spacing that each stringer will take one-third the track load or two-thirds of one rail load. Figure 4(b) shows the elastic curve of the tie and the loads imposed on it. Since the three stringers are to get equal loads, their deflections will be equal; then a tangent to the elastic curve at *B* will pass through the two outer points of support *A, A.* Figure 4(c) is the moment diagram, it being drawn in the same manner as in Fig. 3(b). The moment diagram is first drawn above *ABA* for the two loads *W, W* on a span of $2x$; then the diagram below *ABA* is drawn for a single reaction of $\frac{2}{3}W$ at the center. The amounts of the maximum moments are given in the figure. Following are the areas, moment arms, and area moments for those parts of the moment diagram between *A* and *B:*

	Area	Moment arm from A	Area Moment
I	$+W(x-a)a$	$\left(x-\frac{a}{2}\right)$	$+Wa(x-a)\left(x-\frac{a}{2}\right)$
II	$+W\left(x-a\right)^2\frac{1}{2}$	$\frac{2}{3}\left(x-a\right)$	$+\frac{W}{3}\left(x-a\right)^3$
III	$-\frac{Wx}{3}\cdot\frac{x}{2}$	$\frac{2}{3}x$	$-\frac{Wx^3}{9}$

$$d = Wa\left(x-a\right)\left(x-\frac{a}{2}\right)+\frac{W}{3}\left(x-a\right)^3-\frac{Wx^3}{9}=0$$

We may cancel W from the above equation. E and I have been omitted, as they are constant and would appear in each term. Reducing the equation to its simplest form

$$x^3-\frac{9}{4}a^2x+\frac{3}{4}a^3=0$$

If we assume $a=29.5$ in. and solve this equation by trial, x is found to be 38.1 in.

The foregoing illustrations give only a hint as to the great number of problems that can be solved by the application of area moments. By working out a few cases one can fix the rules in his mind so that a great many problems involving statically indeterminate stresses can be solved without referring to a text-book for a method to follow. For some of the more complicated structures it is probable that the application of area moments will prove no shorter than some of the other methods. The case, however, of the three-legged stiff frame, analyzed by Mr. Stineman, happens to be such that the application of area moments gives a somewhat shorter solution than the Principle of Least Work.

Figure 5 shows a three-legged stiff frame, the posts of which are assumed hinged at the bottom. A longitudinal force P applied to the top girder induces the six forces, H_1, H_2, H_3, V_1, V_2 and V_3, which are statically indeterminate. The dimensions of the frame are as indicated in the figure.

Figure 6 is an exaggerated deflection diagram. Since actual deflections are very small, it is assumed that *A, B* and *C* move forward equal distances d_0 in a horizontal line. The change in length of members due to direct stress is so small that its effect is neglected. The reference line from which all deflections are to be calculated should be taken tangent to the elastic curve at some point preferably where the curve is horizontal or vertical. Since we do not know the location of such a point in this figure the reference or base line will be chosen tangent to the top girder at *B*. *A, B* and *C* being on a straight line, the deflections or displacements, d_4 for *A* and d_5 for *C,* from the tangent through *B,* will be proportional to their distances from B. The angle that this tangent makes with a horizontal line is expressed by

$$\triangle = \frac{d_4}{s_1} = \frac{d_5}{s_2}$$

Reference lines AD_1, BE_1 and CF_1 are drawn perpendicular to the base line or tangent through B, therefore

$$+a = \triangle l_1 = \frac{l_1}{s_1} d_4 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$+b = \triangle l_2 = \frac{l_2}{s_1} d_4 = \frac{l_2}{s_2} d_5 \quad \ldots\ldots\ldots\ldots (2)$$

$$+c = \triangle l_3 = \frac{l_3}{s_2} d_5 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The above displacements *a, b* and *c,* are positive as they extend from their reference lines in a counter-clockwise direction about the origin B. The displacements d_1, d_2 and d_3 are also positive in direction and are obtained as results of summing up changes of inclination of the elastic curve from the point B to the respective points *D, E* and *F*. The relations of the different displacements to each other, as obtained from the deflection diagram, are as follows:

$$d_0 = d_2 - b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$d_1 = d_0 + a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$d_3 = d_0 + c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\frac{d_4}{s_1} = \frac{d_5}{s_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Substituting in equations (5) and (6) the values of *a, b, c* and d_0 as given in equations (1), (2), (3) and (4);

$$d_1 = d_2 - b + a = d_2 - \frac{l_2}{s_1} d_4 + \frac{l_1}{s_1} d_4 = d_2 - d_4 \frac{l_2 - l_1}{s_1} \quad \ldots\ldots (8)$$

$$d_3 = d_2 - b + c = d_2 - \frac{l_2}{s_2} d_5 + \frac{l_3}{s_2} d_5 = d_2 - d_5 \frac{l_2 - l_3}{s_2} \quad \ldots\ldots (9)$$

By writing area moment expressions for d_1, d_2, d_3, d_4 and d_5 and substituting in equation (7), (8) and (9), three independent equations are obtained in terms of the unknown forces shown in Fig. 5. The fundamental static equations, $\Sigma H = O$, $\Sigma V = O$ and $\Sigma M = O$, will give three more equations, making six in all, from which the six unknown forces, H_1, H_2, H_3, V_1, V_2 and V_3, may be found.

Figure 7 is a diagram of the moments produced by the assumed forces. Moments in a counter-clockwise direction are assumed positive, those in the opposite direction, negative, the same as noted for deflections about the origin. It is assumed that V_1,

V_2 and V_3 act upward. If any of them act in the opposite direction its sign will come out negative. For reference, the different moment areas are designated by Roman numerals. Following are the areas of the different divisions of the figure in terms of the unknown forces and the dimensions of the frame;

Division	Area	Division	Area
I	$+\frac{H_1 l_1^2}{2}$	V	$+H_3 l_3 s_2$
II	$+H_1 l_1 s_1$	VI	$+\frac{V_3 s_2^2}{2}$
III	$-\frac{V_1 s_1^2}{2}$	VII	$+\frac{H_3 l_3^2}{2}$
IV	$+\frac{H_2 l_2^2}{2}$		

Combining these areas with the moment arms given in Fig. 7, in accordance with rule 2 for area moments, and multiplying each expression by $\frac{1}{I}$ for its particular member;

$$d_1 = \frac{H_1 l_1^2}{2I_1} \cdot \frac{2}{3} l_1 + \frac{H_1 l_1 s_1}{I_4} \cdot l_1 - \frac{V_1 s_1^2}{2I_4} \cdot l_1 = \frac{H_1 l_1^3}{3I_1} + \frac{H_1 l_1^2 s_1}{I_4} - \frac{V_1 l_1 s_1^2}{2I_4}$$

$$d_2 = \frac{H_2 l_2^2}{2I_2} \cdot \frac{2}{3} l_2 = \frac{H_2 l_2^3}{3I_2}$$

$$d_3 = \frac{H_3 l_3^2}{2I_3} \cdot \frac{2}{3} l_3 + \frac{H_3 l_3 s_2}{I_4} \cdot l_3 + \frac{V_3 s_2^2}{2I_4} \cdot l_3 = \frac{H_3 l_3^3}{3I_3} + \frac{H_3 l_3^2 s_2}{I_4} + \frac{V_3 l_3 s_2^2}{2I_4}$$

$$d_4 = \frac{H_1 l_1 s_1}{I_4} \cdot \frac{s_1}{2} - \frac{V_1 s_1^2}{2I_4} \cdot \frac{2}{3} s_1 = \frac{H_1 l_1 s_1^2}{2I_4} - \frac{V_1 s_1^3}{3I_4}$$

$$d_5 = \frac{H_3 l_3 s_2}{I_4} \cdot \frac{s_2}{2} + \frac{V_3 s_2^2}{2I_4} \cdot \frac{2}{3} s_2 = \frac{H_3 l_3 s_2^2}{2I_4} + \frac{V_3 s_2^3}{3I_4}$$

E was omitted as it is constant throughout and would not affect the results if used. Substituting the above values in equations (7), (8) and (9):

$$\frac{H_1 l_1 s_1}{2I_4} - \frac{V_1 s_1^2}{3I_4} = \frac{H_3 l_3 s_2}{2I_4} + \frac{V_3 s_2^2}{3I_4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$\frac{H_1 l_1^3}{3I_1} + \frac{H_1 l_1^2 s_1}{I_4} - \frac{V_1 l_1 s_1^2}{2I_4} = \frac{H_2 l_2^3}{3I_2} - \left(\frac{H_1 l_1 s_1}{2I_4} - \frac{V_1 s_1^2}{3I_4}\right)(l_2 - l_1) \quad \ldots (11)$$

$$\frac{H_3 l_3^3}{3I_3} + \frac{H_3 l_3^2 s_2}{I_4} + \frac{V_3 l_3 s_2^2}{2I_4} = \frac{H_2 l_2^3}{3I_2} - \left(\frac{H_3 l_3 s_2}{2I_4} + \frac{V_3 s_2^2}{3I_4}\right)(l_2 - l_3) \quad \ldots (12)$$

Expanding, clearing of fractions, and collectng terms, these three equations reduce to the following:

$$+H_1 . 3l_1 s_1 - H_3 . 3l_3 s_2 - V_1 . 2s_1^2 - V_3 . 2s_2^2 = O \quad \ldots\ldots\ldots\ldots (13)$$

$$+H_1 \left[\frac{2l_1^3}{I_1} + \frac{3l_1 s_1}{I_4}\left(l_1+l_2\right)\right] - H_2 \frac{2l_2^3}{I_2} - V_1 \frac{s_1^2}{I_4}\left(l_1+2l_2\right) = O \quad (14)$$

$$+H_3 \left[\frac{2l_3^3}{I_3} + \frac{3l_3 s_2}{I_4}\left(l_3+l_2\right)\right] - H_2 \frac{2l_2^3}{I_2} + V_3 \frac{s_2^2}{I_4}\left(l_3+2l_2\right) = O \quad (15)$$

The three static equations are as follows:

$$H_1+H_2+H_3-P=O \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

$$V_1+V_2+V_3=O \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

$$H_1 l_1 + H_2 l_2 + H_3 l_3 - V_1 s_1 + V_3 s_2 = O \quad \ldots\ldots\ldots\ldots (18)$$

If we substitute in equations (14), (15) and (18) the values of H_2 and V_1 as given in equations (16) and (13), respectively, we will obtain the three following equations in terms of the three unknown forces, H_1, H_3 and V_3:

$$+H_1\left[\frac{2l_1^3}{I_1} + \frac{2l_2^3}{I_2} + \frac{3l_1^2 s_1}{2I_4}\right] + H_3\left[\frac{2l_2^3}{I_2} + \frac{3l_3 s_2}{2I_4}\left(l_1+2l_2\right)\right]$$

$$+V_3 \frac{s_2^2}{I_4}\left(l_1+2l_2\right) - P\left(\frac{2l_2^3}{I_2}\right) = O \quad \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

$$\left(+H_1 \frac{2l_2^3}{I_2}\right) + H_3\left[\frac{2l_2^3}{I_2} + \frac{2l_3^3}{I_3} + \frac{3l_3 s_2}{I_4}\left(l_3+l_2\right)\right] + V_3 \frac{s_2^2}{I_4}\left(l_3+2l_2\right)$$

$$-P\left(\frac{2l_2^3}{I_2}\right) = O \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (20)$$

$$+H_1\left(l_1+2l_2\right) - H_3\left[l_3\left(\frac{3s_2}{s_1}+2\right) - 2l_2\right] - V_3 . 2s_2\left(1+\frac{s_2}{s_1}\right)$$

$$-P . 2l_2 = O \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

After solving the above simultaneous equations for H_1, H_3 and V_3 the values of H_2, V_1 and V_2 can be found from the following:

$$H_2 = P - H_1 - H_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (22)$$

$$V_1 = \frac{H_1 . 3l_1 s_1 - H_3 . 3l_3 s_2 - V_3 . 2s_2^2}{2\, s_1^2} \quad \ldots\ldots\ldots\ldots (23)$$

$$V_2 = -V_1 - V_3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (24)$$

Take, for example, the following special case, which is the same as the one given in Mr. Stineman's paper:

$l_1 = 42.5$	$I_1 = 10I$
$l_2 = 34.0$	$I_2 = I_3 = I$
$l_3 = 29.75$	$I_4 = 8I$
$s_1 = s_2 = 17$	

Substituting in equations (19), (20) and (21), placing $I = 1$, and dividing through each equation by its coefficient of V_3:

$$+25.0H_1 + 22.3H_3 + V_3 - 19.69P = O$$
$$+22.3H_1 + 40.6H_3 + V_3 - 22.3P = O$$
$$+1.63H_1 - 1.19H_3 - V_3 - 1.P = O$$

Solving for H_1, H_3, V_3 and substituting in equations (22), (23), (24), we find the following reactions:

	Reaction	$P = 120{,}000$ lbs.
H_1	$+0.595P$	+71,500
H_2	$+0.176P$	+21,000
H_3	$+0.229P$	+27,500
V_1	$+1.936P$	+232,500
V_2	$-1.632P$	—196,000
V_3	$-0.304P$	—36,500

These results were obtained with a slide rule and are the same as given in Mr. Stineman's paper, although the algebraic equations have a considerably different form.

Another advantage in the use of area moments is that the results can be checked quickly by substituting them in the area moment expressions for d_1, d_2, d_3 d_4 and d_5 on page 913, then placing the numerical values of these deflections in equations (7), (8) and (9).

M. D. Kolyn: The work of obtaining the equations may be much simplified by remembering that what we are trying to arrive at is not the amount of work done, but that the work done shall be a minimum; that is, the equation which interests us is not that the work done equals $\Sigma \int \frac{M^2}{2EI} \cdot dx$, but that the work done is a minimum, and consequently the system is in equilibrium when $\frac{\delta}{\delta V} \Sigma \int \frac{M^2}{2EI} \cdot dx = O$. Now it may be proved that the order in which the differentiation and integration are performed is immaterial; or, for the case in hand

$$\frac{\delta}{\delta V} \Sigma \int \frac{M^2}{2EI} \cdot dx = \Sigma \frac{\delta}{\delta V} \cdot \frac{M^2}{2EI} \cdot dx = \Sigma \int \frac{M}{EI} \cdot \frac{\delta M}{\delta V} \cdot dx$$

The advantage of this method is that it does away with the squaring of the long moment term for each member, and the consequent page-long integration. Instead we have a series of short differentiations, multiplications and integrations, all of which can be written out in tabular form, and written out directly. This tabulation has the further advantage that in case a change in dimension, section, or applied forces is made, or if an error is found in the work, the effect of such change can quickly and confidently be traced out along its proper column or row.

PROOF THAT

$$\frac{\delta}{\delta V}\int\frac{M^2}{2EI}\cdot dx=\int\frac{M}{EI}\frac{\delta M}{\delta V}\cdot dx$$

Without going into fundamental mathematics, the truth of the equation $\frac{\delta}{\delta V}\Sigma\int\frac{M^2}{2EI}\cdot dx=\Sigma\int\frac{M}{EI}\cdot\frac{\delta M}{\delta V}\cdot dx$ may be seen by considering that the term $\int\frac{M^2}{2EI}dx$ represents the weight of the solid of revolution obtained by rotating the moment diagram about the axis of the member, that is the x axis. The volume of this solid is $\int\pi M^2 dx$; consequently its density must be $\frac{2EI}{\pi}$

Imagine the solid as composed of a large number of slices or laminae of equal thickness Δx and variable height M. The sectional area of each slice is πM^2 and its volume is $\pi M^2\Delta x$.

M is a function of x, V and other variables. At any normal section S, as V increases, the other variables remaining constant, the ratio of increase in value of M to increase in value of V or $\frac{\delta M}{\delta V}$ equals the rate of increase of radius of the laminae. The length δM with radius of rotation M sweeps out an increase in area $2\pi M\delta M$, and increases the volume of the lamina by the volume of the annular ring swept out, which is $2\pi M\ \delta M\ .\ \Delta x$. The rate of increase in volume of the lamina is then $2\pi M\ .\frac{\delta M}{\delta V}\ .\ \Delta x$. Now making the slices infinitely thin and summing them up, we have that the rate of increase in volume in any length $x_1\ x_2$ equals $\int_{x_1}^{x_2}2\pi M\frac{\delta M}{\delta V}dx$, and the rate of increase in weight equals

$$\int_{x_1}^{x^2}\frac{2\pi M\frac{\delta M}{\delta V}dx}{2\pi EI}=\int_{x_1}^{x^2}\frac{M}{EI}\frac{\delta M}{\delta V}dx$$

But the weight equals $\int_{x_1}^{x^2}\frac{M^2}{2EI}dx$; therefore, the rate of increase in weight equals $\frac{\delta}{\delta V}\int_{x_1}^{x^2}\frac{M^2}{2EI}dx$

November, 1914

Therefore $$\frac{\delta}{\delta V}\int_{x_1}^{x^2}\frac{M^2}{2EI}dx = \int_{x_1}^{x^2}\frac{M}{EI}\frac{\delta M}{\delta V}dx$$

CLOSURE.

Mr. Stineman: On the first two pages of my paper an attempt has been made to show, by means of illustrative examples, the necessity of exact formulas for the analysis of structures designed to meet certain conditions. This part of the paper also shows that as the frame becomes more nearly symmetrical, the necessity of exact formulas becomes correspondingly less; but in the latter case the formulas themselves become so greatly simplified that their use involves very little labor.

In the absence of exact formulas, the usual method followed in the design of statically-indeterminate frames consists of making various assumptions, some of which have been mentioned in the paper; but the trouble with making assumptions is that we have no way of knowing how near we are right or how far we are wrong. It therefore seems desirable to reduce the field of assumptions wherever this can be done in an effective manner. The frame treated in this article belongs to a type which occurs frequently in practice; hence the logical thing to do is to derive formulas for the analysis of the general case in Fig. 2, thereby furnishing a means for the definite solution of this particular type. Other types will necessarily require separate treatment; but general formulas for their solution may be derived in a manner similar to the method here given.

Near the end of the article a method is given by which the designer may reduce the moments in the upper part of the structure by taking into account the moments which the column bases are capable of taking. This part is not intended to be mathematically accurate, but it gives an approximate method which is based upon the character of the foundation material. Professor Richey, in his letter, has taken exception to the method given, and proposes to begin by assuming points of contraflexure somewhere between their limiting positions. His objection is perhaps well taken, for it does look more sensible to assume at once the positions of the points of contraflexure. To be consistent, each point of contraflexure should be chosen at a distance above the base such that the ratio of this distance to the column length will be the same for each column. The value of this ratio should be determined from the designer's knowledge of the character of the foundation material. It should be understood, however, that the column footings should then be examined for extreme toe pressure, and they should be made large enough to keep this pressure within reasonable limits. For this purpose the formula following Fig. 11 should be used, as before, except that it should be solved for unit pressure instead of moment.

But it is reasonable to think that conservative designers would prefer, in all cases except where the foundation material is very firm, to design the upper part of the structure as though the column bases were hinged. The column bases and the lower portions of the columns should then be designed to take all the moment which those parts are likely to get because of partial fixity. In this manner both the upper and the lower part of the frame would be designed conservatively.

There is one more point to which I wish to call attention. In any solution of this kind it is necessary to choose an ideal structure. For example, it is supposed that each of the five members of the frame has a constant moment of inertia throughout its entire length. In practice this will not be absolutely true, for the joints at the intersections of the columns with the cross-girder will probably be strengthened by the addition of fillets. Other small variations will occur. Such variations in the moment of inertia of any given member affect the distribution of the resisting moment in that member. In general, the resisting moment is increased at points where the moment of inertia is increased, and vice versa. However, in an article by S. H. Ingberg in *Engineering and Contracting,* January 17, 1912, it is shown that haunches or fillets must be relatively large before they affect the distribution of the resisting moment to an appreciable extent. For instance, a 2-ft. fillet under the end of a 20-ft. span will have very little influence. It will therefore be possible to design a structure which will very nearly fulfill the conditions imposed in this article.

Mr. Vey, in his discussion, has brought out a number of good points which engineers may well bear in mind. He has fallen in line with those who think that we should gradually get away from some of our guess-work by developing more accurate methods of analysis. Incidentally, he takes technical instructors to task for their alleged failure to give us definite means for the analysis of advanced types of structures. This is another form of the charge frequently made that engineering text-books do not keep abreast of engineering practice—a charge which contains some basis of fact. In justice to technical instructors, however, we should remember that relatively few of them are in a position to know what types of structures not previously analyzed should receive attention. The designing engineer, on the other hand, frequently encounters types which he would like to use, but he is unable to find formulas which may be properly applied. It therefore behooves him to retain a working knowledge of higher mathematics, so that he may solve his own problems. His mathematics will be less elegant than that of the technical instructor, but the final results will be the same. He will be obliged to carry on the greater part of his investigations outside of office hours, but he will obtain genuine pleasure as a reward. He should, when the opportunity is offered, give the results of his investigations to other engineers, for then, and then only, will his labors be of real benefit to the engineering profession.

Mr. Smith has presented a solution called the method of area moments—a method which also leads to good results. While his final equations appear at first glance to be a little shorter than mine, it should be noted in my equations the coefficient of H_2 in the first, and that of H_1 in the second, are identical. Hence there is very little difference in the two sets of equations. Furthermore, the greater part of the work involved in applying these formulas is the solution of the simultaneous equations after the substitutions are made. Again, it is hardly a point in favor of the method of area moments to say that it does not involve calculus, for the calculus employed in ordinary solutions by the Principle of Least Work is of an elementary character, and may be easily manipulated by anyone who has studied that branch of mathematics. The algebraic reduction, not the calculus, is the work which demands the greatest care and patience, and it naturally follows that the shortest method is the one which contains the least algebra; but on the whole, the shortest method is the one with which the designer is most familiar. Mr. Smith has perhaps unconsciously left the impression that in obtaining solutions by the method of area moments it is only necessary to drop a penny into the slot and receive the answer. His algebraic reduction appears to be short for the simple reason that it is omitted. However, he has done good service in calling attention to that method, and he deserves credit for the manner in which he has presented it. Each of the known methods should be the most suitable one for certain types of structures, and every method which gives results is a good method. It is desirable that means be found whereby the algebraic reductions may be shortened, for the drudgery of that part of the work is not a pleasant remembrance.

IN MEMORIAM

BARNABAS SCHREINER, M. W. S. E.,

Died July 26, 1914.

Barnabas Schreiner was born at Sternhaus, Bavaria, June 11, 1843. After graduation in 1864, he entered the service of the Royal Bavarian Kreis Ban Amt, being employed in the construction and maintenance of public works. In March, 1865, he was mustered into the army as an engineer and devoted his time to plans for military roads, buildings and fortifications. Three years later he entered the construction department of the Bavarian State Railroads and therein received wide experience in railroad construction and flood protection. In January, 1871, he was promoted to Resident Engineer on the Fichtebgebrigs Railroad and a year later entered municipal work as an assistant to the City Engineer of Nurnberg.

In 1873 a general inactivity in engineering work influenced him to come to America. He worked in Columbus, Ohio, as an architectural draftsman until 1874, when he moved to Fort Dodge, Iowa, and engaged with the City Engineer as assistant. He opened a general engineering office in Des Moines in 1878, after two years as an architect's assistant.

In 1884 he was elected City Engineer of Des Moines, and reorganized the business of that office. His work in this capacity was so well appreciated that he was retained in the city's employ for ten years.

He entered the contracting field in 1896, confining his efforts to waterworks improvements and private buildings.

Three years later he took the position of Chief Engineer with the Iowa Falls and Northern Railroad and followed the work to completion in 1901. He was engaged on various railroad surveys until 1905, when he was engaged as engineer for the Des Moines, Winterset and Creston Electric Railway Co. After three years he returned to private practice, which he continued until 1911, when he again took up railroad work as engineer of the projected Milwaukee, Peoria and St. Louis Railroad.

During the fall and winter of 1913 he was engaged on the survey of crossing sites of the Missouri and Yellowstone rivers. Since last spring he was employed on the road survey and bridge work of Mahaska County, Iowa, and on street paving for the City of Pella.

In addition to these accomplishments he was a student of all branches of engineering and the application of efficiency systems in public plants.

Barnabas Schreiner died at Des Moines, Iowa, July 26, 1914, at the age of 71.

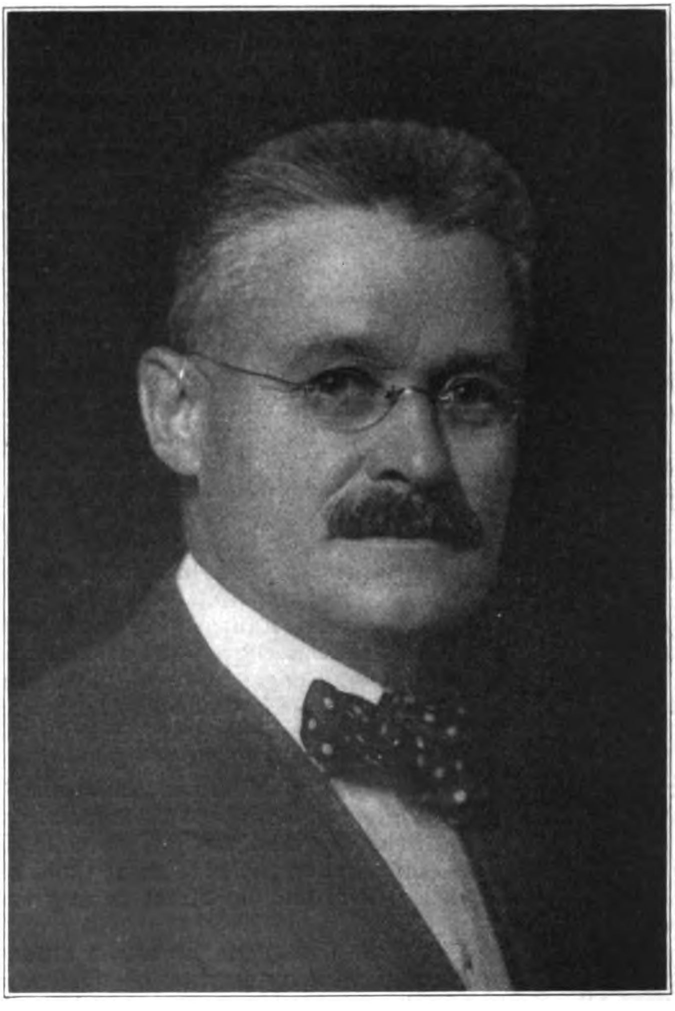
He joined this Society in 1885, but was not a member from

1895 to 1907, when he applied for readmission and was re-elected into membership July 20, 1907.

[The above statement is from William Schreiner at Pella, Iowa, a son of the deceased.]

WILLIAM H. PRATT, M. W. S. E.

Died September 5, 1914



William H. Pratt, who has been a member of this Society since June 5, 1899, passed away in his home at Warwick Road, Kenilworth, in the afternoon of September 5, after a short illness.

Mr. Pratt was born at Norwich, Vt., on October 23, 1852.

His parents were Joseph H. and Ann D. Pratt. He received his first education in his home town and later attended the Dartmouth College, at Hanover, New Hampshire, where he graduated from the Chandler Scientific Department in 1874. After his graduation he took up the work of teaching and for a time pursued this vocation at Dayton, Ohio. About this time the great boom period in American railroad construction began and Mr. Pratt entered into this work as Construction Engineer. In 1880 and 1881 he held the position of Assistant Engineer on the Toledo, Cincinnati and St. Louis Railway. In 1882 he became Principal Assistant Engineer of the Chicago and Indianapolis Air Line Railway, which is now the Chicago, Indianapolis and Louisville Railway. In 1883 he returned to the Toledo, Cincinnati and St. Louis Railway as Chief Engineer of Construction. In 1884 he entered the service of the Morse Bridge Co. at Youngstown, Ohio, and occupied the position of Assistant Superintendent until 1887. In 1887 he became engaged with the Edge Moor Bridge Co. as Engineer of Construction of their new plant, which was then under construction. In 1889 he went with the Mt. Vernon Bridge Co. of Mt. Vernon, Ohio, as Shop Superintendent. In 1890 he was made Manager of this Company, which position he held until 1895, when he engaged in private business as a Contracting Engineer. In 1898 he became Manager of the Universal Construction Co. in Chicago, Illinois. This Company was later merged with the North Works of the Illinois Steel Co., of which he became General Superintendent. At the time of his death he was President of the Illinois Steel Warehouse Co. and General Superintendent of the North Works of the Illinois Steel Co.

Besides being a member of this Society, Mr. Pratt was also a member of the Union League Club, Chicago; the University Club, Chicago; the Chicago Engineers' Club, the Indian Hill Club, Winnetka; the Mercantile Club of St. Louis, the Minnesota Club of St. Paul and the University Club of St. Paul. In his earlier years he took an active interest in the Masonic fraternities and was a thirty-second degree Mason.

Mr. Pratt was a man of strong character, equipped with the ability of making lasting friends, both in connection with his business dealings and in his private life. He was a man of an even and kind disposition, slow in forming his opinions, but after they were formed they proved to be right and stood the test of time. With a definite purpose in view, he worked untiringly for its accomplishment. He gave strength to the community in which he lived and worked, through his well-balanced mind and quieting influence. He had a host of friends in nearly all parts of the country who in sorrow bowed their heads at the receipt of the message which told them that he had passed away. His body is interred in the Mound View Cemetery, Mt. Vernon, Ohio. Mr. Pratt is survived by his widow, Mrs. Elizabeth D. Pratt, two daughters, Ellen and Louise, and a son, Hazen.

Memoir prepared by John Brunner, W. H. Finley and W. M. Hughes, Committee.

November, 1914

PROCEEDINGS OF THE SOCIETY

MINUTES OF THE MEETINGS

Regular Meeting November 2, 1914

A regular meeting (No. 876) was held Monday evening, November 2, 1914. President Lee called the meeting to order at 8 p. m. with about 90 members and guests in attendance.

The Secretary reported from the Board of Direction that at their meeting held in the afternoon, the following had been elected into the Society:

Thomas Grover Dunn, Gorham, Ill..................Associate Member
Arthur A. Heeren, 6135 Peoria St., Chicago.............Junior Member
Albert Austin Chenoweth, 801 Salisbury St., W. Lafayette, Ind., ...Junior Member

Also Ralph A. Bennitt, now of Chicago, who had been duly elected January 2, 1914, an Associate Member, had gone west and had been lost sight of, had just returned to Chicago. At his request the Board of Direction had re-elected him an Associate Member.

Applications for admission to the Society were presented to the Board of Direction as follows:

No. 55, Eugene Adolph Anderson, Evanston, Ill.
No. 56, Victor H. Bell, Calexico, Calif., transfer.
No. 57, Clarence Sage Roe, 506 S. Capital Ave., Lansing, Mich.
No. 58, Marion Den Herder Kolyn, 849 N. La Salle St., Chicago.
No. 59, Horace M. Beebe, 743 Oakwood Blvd., Chicago.

There being no other business, President Lee stated that Dr. George B. Young, Health Commissioner, who had been expected to address the meeting, was sick and could not appear.

President Lee introduced Mr. Howard F. Weiss, of Madison, Wis., Director of the Forest Products Laboratory, who described "The Work and Some Accomplishments of the Forest Products Laboratory." Many stereopticon views were exhibited in illustration. Discussion followed from Messrs. A. T. North, W. C. Armstrong, Albert Cone, F. E. Davidson, W. C. Bauer, J. F. Hayford, and L. E. Cooley, with replies and explanations from Mr. Weiss.

Meeting adjourned about 10:15 p. m., when refreshments were served.

Extra Meeting, November 9, 1914

An extra meeting of the Society (No. 877) was held Monday evening, November 9, 1914. The meeting was called to order at 7:30 p. m., Vice-President Grant in the chair, with about 115 members and guests in attendance. There was no business before the meeting, and the Chairman introduced Mr. L. S. Marsh, Mem. Am. Chem. Soc., and chemist for the city, who addressed the meeting on "High Explosives." The address was allustrated by use of lantern slides and also a few demonstrations.

Discussion followed from Messrs. E. R. Shnable, H. S. Baker, O. P. Chamberlain, Chief McDonnell of the Fire Prevention Bureau, Ernest McCullough, V. R. Walling, H. E. Goldberg, E. E. R. Tratman, L. E. Ives, F. G. Vent, E. F. Smith, W. W. DeBerard, and F. J. Postel, with replies and explanations from Mr. Marsh.

Meeting adjourned at 10 p. m.

Extra Meeting, November 16, 1914

Meeting (No. 878), being an extra meeting in the interest of the Hydraulic, Sanitary and Municipal Section, was held Monday evening, November 16.

Mr. W. D. Gerber, Chairman of the Section, called the meeting to order at 7:50 p. m., there being about fifty members and guests present.

There being no business before the Section, Mr. Gerber introduced Mr. J. W. Link, who read a very interesting paper on "The Coon Rapids Low Head Hydro-Electric Development on the Mississippi River Near Minneapolis, Minn." The paper was well illustrated by stereopticon views.

The points brought out by Mr. Link led to an extensive discussion by Messrs. Mehren, Link, Blanchard, DeBerard, Goldberg, Cooley, Coffin, Lake, Brandon, and W. T. Barnes. Mr. Barnes had some interesting lantern slides to show "what not to do."

Extra Meeting, November 24, 1914

An extra meeting of the Society (No. 879), a joint meeting of the Electrical Section with the Chicago Section A. I. E. E. and the Chicago Section of the Illuminating Engineering Society, was held Tuesday evening, November 24, 1914. The meeting was called to order at 7:50 p. m. by Mr. F. J. Postel, Chairman of the Electrical Section, with about 100 members and guests in attendance. He explained how the joint committee had divided the meetings and the subjects among sundry members, and that this evening's meeting, the subject of which was electric lighting, had been allotted to Mr. W. A. Durgin, into whose hands he would now turn over the meeting. The speaker of the evening, Mr. S. E. Doane, Chief Engineer of the National Lamp Works of the General Electric Company, Nela Park, Cleveland, was then introduced by Mr. Durgin with appropriate remarks. Mr. Doane presented his paper, "Electric Lighting—a Factor in Civilization," with some illustrations, lantern slides and apparatus. Discussion followed by Messrs. Durgin, P. Junkersfeld, E. M. Tompkins, J. R. Cravath, E. W. Lloyd, V. H. Tousley, M. G. Lloyd, Albert Scheible, and Prof. W. C. Bauer, with replies and a closure from Mr. Doane.

Meeting adjourned at 10 p. m. J. H. WARDER, Secretary.

BOOK REVIEWS

THE BOOKS REVIEWED ARE IN THE LIBRARY OF THE SOCIETY

STRUCTURAL ENGINEERS' HANDBOOK. By Milo S. Ketchum, C. E. The McGraw-Hill Book Company, New York, 1914. Leather, 6½ by 9 ins., pp. 900 plus xvi, 260 tables, 400 illustrations in the text. Price, $5.00 net, postpaid.

This book is somewhat more than a handbook, and can almost be called an encyclopedia on structural engineering. The author's inclusion of concrete and substructure work generally, as absolutely within the province of structural engineering, is in line with present day ideas and is entirely correct.

Portions of other books published by the same author are included in this volume, so as to make it complete within itself.

The tables given are very voluminous and are carried to greater limits than usually found in handbooks. Some of the tables are original with the author and should be of considerable aid to structural designers. The other tables are standard and are well known, being taken from the Cambria Steel Co., Carnegie Steel Co., American Steel & Wire Co., National Tube Co., Bethlehem Steel Co., and other handbooks. In fact, with this book in the engineer's possession, about the only other books of tables needed by him would be a book of logarithms, and a table of squares of feet, inches and sixteenths.

One of the features of the book is the large amount of data collected from many sources, bearing on the various subjects treated. This portion of the work apparently has been done in a very thorough and painstaking manner, and is to be highly commended. Credit is invariably given to the sources of information, so that the engineer investigating a particular subject is enabled to go to the original articles to which reference is made.

The excellent nomenclature, definitions and specifications adopted by the American Railway Engineering Association are generally followed by the author. The drawings from which the cuts have been made are a good guide for the young draftsman to follow. The letters are of the type generally adopted for structural work drawings. The foreword, or introduction, to the book is especially well written and repays careful reading, showing the clarity of the author's reasoning with regard to the fundamental principles underlying design.

The general ideas regarding the making of estimates, of economic design, the balancing of opposing elements, economy of material, simplicity of members and ease of shopwork are very well stated.

The book is composed of two parts. One hundred and sixty-five tables compose part two.

Part one is composed of seventeen chapters as follows, which show the wide range of subjects covered.

I. Steel Roof Trusses and Mill Buildings.
II. Steel Office Buildings.
III. Steel Highway Bridges.
IV. Steel Railway Bridges.
V. Retaining Walls.
VI. Bridge Abutments and Piers.
VII. Timber Bridges and Trestles.
VIII. Steel Bins.
IX. Steel Grain Elevators.
X. Steel Head Frames and Coal Tipples.
XI. Steel Stand-Pipes and Elevated Tanks and Towers.
XII. Structural Drafting.
XIII. Estimates of Structural Steel.
XIV. Erection of Structural Steel.
XV. Engineering Materials.
XVI. Structural Mechanics.
XVII. The Design of Steel Details.

These chapters are all handled on the, more or less, general plan of giving nomenclature; definitions of terms; details of construction; forms of sections; examples showing actual construction; imposed loads; estimates of weights; methods of computation, graphical and analytical; specifications; etc.

It is a very good reference book for the use of structural engineers, and is well worthy of a place in their libraries.

In getting out a book of this kind, a great responsibility is imposed upon the author. As stated by the author: "This book is written for the structural engineer and for the student or engineer who has had a thorough course in applied mechanics and the calculation of stresses in structures . . . and is intended as a working manual for the engineer, draftsman and student." Extreme care must be taken not to mislead the student or young engineer or draftsman who uses it for information regarding the problem in hand. Unlike the practicing engineer of mature judgment who is able to discriminate, the young engineer is likely to blindly follow all the details of a design shown as having been built, believing it to be an example of good practice, when in fact such practice may have been discarded many years ago.

The author should have been somewhat more careful with regard to some of the examples shown, although very little criticism can be offered. Unfortunately, he shows some examples which are likely to mislead the young engineer or draftsman.

Attention is called to the following pages which illustrate this point:

Page 120—The pony truss does not show any support to the top chord and would certainly be wabbly.

Page 194—Quadruple intersection riveted truss span. This is shown as a type. The truth is that the floor of this particular bridge was designed by the Northwestern Railway to meet a condition where an absolutely minimum depth from base of rail to low iron was essential. Large economies were effected by reducing this distance to two feet. It would certainly be very poor engineering to put in such a floor when plenty of head-room could be obtained.

Page 391—Joint of roof truss. This method of detail is very confusing and does not accord with any known practice used in bridge or building detail offices.

Page 393—Roof truss. The bearing detail of this is very poor and gives a kind of hinge action.

Page 475—Falsework bents. This shows iron straps connecting posts to the cap. This practice has now been entirely dispensed with.

It is appreciated, however, that in getting out a book of this size with as ambitious a purpose as the author seems to have had, such things will invariably creep in. The author is to be congratulated on having so few examples of poor design when there is hardly a book published today from which such errors have been completely eliminated.—I. F. S.

STRENGTH OF MATERIALS. By H. E. Murdock, second edition, revised and enlarged. New York, 1914, John Wiley & Sons, Inc. Cloth bound, 5 by 7½ in., 352 pages, with index, many illustrations and tables.

An earlier edition of this book was reviewed in our JOURNAL, Vol. XVI., page 929, November, 1911. This present volume has been somewhat enlarged, but has not been changed essentially. It contains eighteen chapters and an appendix "A" of 28 pages relating to the subject of Centroids and Moments of Inertia of Areas. Materials of Construction is the subject of Chapter I, while the topic of Direct Stresses follows in the next chapter. Applications of Direct Stresses is in Chapter III and followed by Riveted Joints. Chapters V and VI treat of Beams under External and Internal Flexural Forces. Stresses in structures as dams, walls, piers and chimneys is the subject of Chapter VII, and is followed by Graphic Integration in the next chapter. Chapters IX to XIII, inclusive, treat of the broad subject of Beams, the Elastic Curve, the determination of this by the algebraic method and Secondary Stresses, covering about 90 pages. Examples and problems are included in these chapters. Next follows Chapter XIV treating of Columns and Struts, while Torsion is the subject of the following chapter, and this is followedby Chapter XVI concerning Repeated Stresses, Resilience and Hysteresis. The subject of Reinforced Concrete Beams and Columns is taken up in the closing chapters of the book and covers over 40 pages. Following this is Appendix A—Centroids and Moments of Inertia of Areas, which includes centroids of various shaped areas, moment of inertia, radius of gyration and polar moment of inertia, relation between moments of inertia under various conditions, moments of inertia of composite areas, and ending with a series of examples to be solved by the student. The book concludes with a series of tables and diagrams, arranged for easy reference in the course of study and the solution of the examples scattered through the book. The book is essentially a textbook arranged by a professor of an engineering school and with the main object of instruction of undergraduates. For such a purpose it seems to be very well adapted.

POLYPHASE CURRENTS (second edition). By A. Still of the Dept. of Electrical Engineering of Purdue University. The Macmillan Co., New York, 1914. Cloth; 5 by 8 inches; 300 pages, including index; diagrams and drawings. Price, $1.50.

Mr. Still, realizing the demand for a book treating the subject of theoretical conditions in polyphase working and written in such a manner as to be commendable to students and engineers not having sufficient mathematical knowledge to use advantageously the more advanced works, prepared the first edition of this book. This second edition has been prepared with but little addition of subject matter, but with a careful redrawing and rearrangement of diagrams to conform to the accepted conventions.

A concise treatment of the elementary principles of alternating currents, given in the first chapter, is the keynote to the succeeding chapters which take up in order Polyphase Currents, Polyphase Circuits, Polyphase Transformers, Transmission, Polyphase Induction Motors, and Asynchronous Generators, Frequency Converters, Compensated Induction Motors, and Rotary Converters.

Mathematical developments are avoided as far as possible but their absence is more than replaced by the numerous diagrams and figures which are more acceptable to the class of students for which the book is intended. Mathematical development and graphic representation have been combined with excellent results. Paragraph headings in black-face type make the book a satisfactory one for reference.

The book is concluded with an appendix in two parts under the headings, On the Relation Between Magnetic Flux and Induced E. M. F. in a Circuit Conveying an Alternating Current, and Method of Drawing the Complete Vector Diagram for a Polyphase Induction Motor from Three Sets of Measurements Made on the Machine, which are not essential to the body of the book but are nevertheless valuable in themselves.

In a few words, the book is a commendable one to students and practical engineers who are seeking an introductory work on the design of polyphase machinery.

STEEL CONSTRUCTION; a text and reference book covering the design of steel framework for buildings. By Henry Jackson Burt, C. E., Structural Engineer for Holabird & Roche, Architects. American Technical Society, Chicago, 1914. Flexible leather, 4½ by 7 in.; 372 pages; well illustrated. Price, $2.75.

This work, in handbook form, is very well set up. It has many illustrations, diagrams, and tables, but does not repeat the tables found in the steel manufacturers' handbooks.

It is an up-to-date discussion of a subject heretofore not comprehensively treated in book form, the matter, for the most part, being all new material, carefully selected and well written.

The twenty-five pages devoted to a discussion of metallurgical practice and process of manufacture, it appears, could have been better used in treating other problems which arise in steel building design and construction.

There is little or nothing said about erection problems.

The headings of chapters are as follows: Steel Sections, Quality of Material, Unit Stresses, Rivets and Bolts, Beams, Riveted Girders, Compression Members, Tension Members, Wind Bracing, Practical Design, Protection of Steel, Specifications, and Index. W. A. H.

REPORT OF THE CITY WASTE COMMISSION OF THE CITY OF CHICAGO. This is a pamphlet 6 by 9 in. in size, of about 70 pages, containing a good deal of valuable information on the subject of city wastes and their collection and disposal.

The commission was created by order of the Chicago City Council, to make a comprehensive study and report on the subject of collection, delivery, and disposal of garbage and waste. The members of the commission included Ald. Willis O. Nance, M. D., chairman; George B. Young, Commissioner of Health; Ald. Charles E. Merriam; Hon. L. E. McGann, Commissioner of Public Works; Col. Henry A. Allen, M. E., Consulting Engineer; Mrs. W. B. Owen; Miss Mary McDowell, and some others.

At a meeting of the City Council in session June 14, 1914, it was "Resolved, That the City Council do and hereby does accept in principle the conclusions set forth in the report of the Waste Commission." Early in the history of this commission the services of experts to assist in the solution of the problems were secured. These experts were John T. Fetherston of New York, and Irwin S. Osborn of Toronto, Can. They were engaged "to make an investigation of the various methods necessary for the collection, delivery and disposal of garbage, refuse and waste in behalf of the City of Chicago and render a report thereon." The several subjects and divisions of the report—nine in all—are enumerated. The report contains General Conclusions, Recommendations and Project for Disposal. Following the report signed by the committee, is "Enclosure A," addressed to Ald. W. O. Nance, chairman of the commission, signed by the experts, Messrs. Osborn and Fetherston, which is their report on the situation, their recommendations, a series of projects, and much tabular matter with diagrams in explanation of the same. The commission has shown great diligence and judgment in the collection of data pertaining to collection and disposal of city wastes, which are embodied in this report, and which will serve a very useful purpose to other investigators at other times and places.

REPORT OF THE PHILADELPHIA DEPARTMENT OF PUBLIC WORKS. Annual report of the director of the Department of Public Works, for the year ending Dec. 31, 1913. Mr. M. L. Cooke, director. Pamphlet 6 by 9 in.; 48 pages.

This report, vastly differing with the usual municipal report, in that it has presented the salient facts in a form acceptable to the average reader who hasn't the time to arrive at conclusions by exhaustive study of long columns of tabulated data, is a record of the efforts of a public works department to depart from the usual methods of administration, and to adopt the new idea of municipal management, that is, the methods generally accepted by the more important commercial and industrial organizations.

Mr. Cooke's open frankness as regards certain factors which hampered the city's progress is remarkable. Truly he "hewed to the mark and let the chips fall where they would," sparing no offender regardless of position or influence.

In every important issue Mr. Cooke, realizing the ultimate economy of good counsel, sought the foremost experts of the country, in face of every obstacle the city council could place before him. As a result of this opposition a majority of these experts gave their services gratis or were paid by private subscription.

But in face of all these accomplishments the director warns against undue elation by stating that at the time of writing the department has but made a good start in the work it intends to perfect, and that practically all the methods now in use will be replaced by better ones in the future. Such a spirit as this can but succeed and the results of this splendid work are eagerly anticipated by all who are interested in the newer ideas along municipal administration.

BUSINESS METHODS IN MUNICIPAL WORK, an Informal Record of the Operations of the Department of Public Works of Philadelphia, 1913. Pamphlet 6 by 9 inches; 64 pages.

In the beginning an open letter to Mayor Blankenburg sets forth the principles adopted and the ends to which their efforts have been directed, i. e., to quote Mr. Cooke, "We have worked on the theory that those who were responsible for your election would, by no means, be satisfied with simply an honest administration—that they expected us rather to assume the honesty, and demand efficiency and progress." Thereafter he explains certain definite procedures in the management of employees as regards relations with contractors, interpretations of contracts and specifications, relations of city employees in the case of damage suits against the city, the possibility of employees being interested in purchases made without public competitive bidding, employees' use of liquor, financial obligations, and gives some specific instances.

Following, he takes up in detail the various practices which made possible the efficient system of administration, such as, Reorganization, Status of the Employee, Educational Work for the Employee's Benefit, Discipline and Discharge, Political Cases, Economies: in Operation, Maintenance and Construction, New Positions, Contracts, and Consideration for, and Cooperation with the Public, all of which are well explained with data and examples. In all his workings it can be seen that he has closely adhered to the modern method accepted by the large industrial and commercial organizations.

This pamphlet is only one of many which Mr. Cooke has prepared, showing the workings and results of a real efficiency system as applied to municipal management, and it is hoped that others will follow with equally valuable messages to the tax-paying public and its officials.

SURVEYING MANUAL, Designed for the Use of First-year Students in Surveying and Especially for the Use of Non-Civil Engineering Students. By Howard Chapin Ives, Professor of Railroad Engineering, Worcestor Polytechnic Institute. First Edition, New York, 1914. John Wiley & Sons, VIII; 295 pages, 55 figures, 42 samples of field notes. XIII mathematical tables. Price $2.25 net.

This book is prepared principally for class work and contains a number of problems set for students with suggestions for approved methods of working the problems and keeping the field notes. It is in effect a condensed treatise on surveying, the subject being taught by the "laboratory method." Mc. C.

REPORT ON SERVICE TEST ROAD. Byberry and Bensalem Turnpike. Philadelphia, November, 1913, Department of Public Works, Bureau of Highways, by Wm. H. Connell, Chief of the Bureau of Highways. Pamphlet 7 by 10 inches, 62 pages, text, and 30 full page illustrations.

With the present increased interest in public highway and road construction, this pamphlet is full of value and is very timely, as showing what is being done in Philadelphia in the study of road materials and methods of construction. This experimental piece of road 3.4 miles in length, is part of the old traveled highway to Trenton and beyond, and is in the northeastern part of Philadelphia. The road was divided into twenty-six sections of various lengths from 300 to 3,700 feet.

The construction of these several sections, materials used, method of construction, and costs are all recorded in detail. The different sections of roadway included different kinds of bituminous combinations, as the mixing methods, penetration methods, and with different varieties of asphaltic or bituminous binders; also variations in the base course as concrete and vitrified block. These are all noted in detail in the descriptions of the several sections of the road. The costs per unit of the several sections are also recorded in detail.

It will be interesting to note the result of wear on this roadway, where the destructive conditions can be assumed as fairly uniform on the whole length, but where the resistance to destruction under the passing automobiles may be different in two adjacent sections.

It is to be hoped that the public may have full benefit of this experiment by other publications from the Philadelphia Department of Public Works, Bureau of Highways, recording in detail the results obtained from this Service Test Road.

LIBRARY NOTES

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts the following publications have been received:

NEW BOOKS.

McGraw-Hill Book Co.:
  Structural Engineers' Handbook, M. S. Ketchum. Leather.
  The Regulation of Rivers, J. L. Van Ornum. Cloth.

American Technical Society:
- Steel Construction, H. J. Burt. Leather.

John Wiley & Sons, Inc.:
- Surveying Manual, H. C. Ives. Leather.

Open Court Publishing Co.:
- Essays on the Life and Works of Newton, Augustus DeMorgan. Cloth.
- Waves of Sand and Snow, Vaughan Cornish. Cloth.

Macmillan Company:
- Polyphase Currents, Alfred Still. Cloth.

MISCELLANEOUS GIFTS.

Coal Mine Managers, Colorado:
- Facts Concerning the Struggle in Colorado for Industrial Freedom. Pam.

Carnegie Endowment for International Peace:
- Report of International Commission to Inquire Into the Cause and Conduct of the Balkan Wars. Cloth.

Chicago Special Park Commission:
- Annual Report, 1913. Pam.

Ernest McCullough, M. W. S. E.:
- Brücken in Eisenbeton, C. Kernsten. Cloth.

Jacob T. Wainwright:
- Is the Efficiency of a Thermodynamic Reversible Cycle Independent of the Working Medium? Wainwright. Bds.

EXCHANGES.

Iowa State College Engineering Experiment Station:
- Bulletin No. 37, Illuminating Power of Kerosene. Pam.

Engineering Association of New South Wales:
- Proceedings, Vol. 28, 1912-13. Cloth.

Institution of Mechanical Engineers:
- Proceedings, July, 1914. Paper.

Canada Department of Mines:
- Gold Fields of Nova Scotia. Pam.
- Lode Mining in Yukon. Pam.
- The Copper Smelting Industries of Canada. Pam.

Maine State Highway Commission:
- Annual Report, 1913. Cloth.

Institution of Civil Engineers:
- Minutes of Proceedings, September, 1914. Paper.

American Society for Testing Materials:
- Year Book, 1914, containing Standing Specifications. Cloth.

National Association of Cotton Manufacturers:
- Transactions, 1914. Bds.

Canadian Society of Civil Engineers:
- Transactions, Jan.-June, 1914. Paper.

University of Missouri Engineering Experiment Station:
- A Study in the effects of Heat on Missouri Granites. Pam.

Illinois State Water Survey:
- Report for year 1913. Cloth.

University of Minnesota:
- Minnesota Public Utility Rates: Gas, Electric, Water. Paper.

Philadelphia Bureau of Surveys:
- Annual Report, 1913. Cloth.

New York Public Service Commission; First District:
- Annual Report, 1912, Vol. III. Cloth.

GOVERNMENT PUBLICATIONS.

U. S. Geological Survey:
- The Production of Magnesite in 1913. Pam.
- The Production of Antimony, Arsenic, Bismuth, Selenium, Tellurium in 1913. Pam.
- The Production of Borax in 1913. Pam.
- The Production of Asphalt, Related Bitumens and Bituminous Rock in 1913. Pam.

GOVERNMENT PUBLICATIONS.

The Production of Iron Ore, Pig Iron and Steel in 1913.
The Production of Lime in 1913. Pam.
The Production of Platinum and Allied Metals in 1913. Pam.
The Manufacture of Coke in 1913. Pam.
Gold, Silver, Copper, Lead and Zinc in Colorado in 1913. Pam.
Gold, Silver, Copper, Lead and Zinc in Utah in 1913. Pam.
Gold, Silver, Copper, Lead and Zinc in New Mexico and Texas in 1913. Pam.
Gold, Silver, Copper, Lead and Zinc in California and Oregon in 1913. Pam.
Gems and Precious Stones in 1913. Pam.
Statistics of the Clay Working Industries in 1913. Pam.
Copper in 1913. Pam.
Mineral Resources of the United States in 1912. 2 Vols. Cloth.
Water Supply Papers Nos. 332c, 340c, 363, 364. Pams.
Bulletins Nos. 580j, 581c, 586, 592. Pams.
Gold, Silver, Copper, Lead and Zinc in Montana in 1913. Pam.
Gold, Silver, Copper, Lead and Zinc in Arizona in 1913. Pam.
The Production of Coal in 1913. Pam.
Zinc and Cadmium in 1913. Pam.
The Production of Metals and Metallic Ores in 1912 and 1913. Pam.

U. S. Bureau of Mines:
Technical Paper No. 34, Experiments With Furnaces for a Hand-Fired Return Tubular Boiler. Pam.
Technical Paper No. 63, Factors Governing the Combustion of Coal in Boiler Furnaces. Pam.
Technical Paper No. 79, Electric Lights for Use About Oil and Gas Wells.
Technical Paper No. 77, Report of the Committee on Resuscitation From Mine Gases. Pam.
Technical Paper No. 65, A Study of the Oxidation of Coal. Pam.
Bulletin No. 38, The Origin of Coal. Pam.
Bulletin No. 76, United States Coals Available for Export Trade. Pam.
Miners' Circular No. 16, Hints on Coal-Mine Ventilation. Pam.
Miners' Circular No. 19, The Prevention of Accidents From Explosives in Metal Mining. Pam.
Technical Paper No. 85, Production of Explosives in the United States in 1913. Pam.
Bulletin No. 83, The Humidity of Mine Air. Pam.
Report of Mine Inspector for Territory of Alaska for year ending June 30, 1914. Pam.

U. S. Department of Agriculture:
Bulletin No. 115, Gate Structures for Irrigation Canals. Pam.

Library of Congress:
List of References on Water Rights and the Control of Waters. Pam.

U. S. Public Health Service:
Municipal Ordinances, Rules, and Regulations Pertaining to Public Health. Paper.

MEMBERSHIP

Additions:

Chenoweth, Albert A., Lafayette, Ind	Junior Member
Dunn, Thomas C., Gorham, Ill	Associate Member
Heeren, Arthur A., Chicago	Junior Member

Deceased:
B. Schreiner, Oskaloosa, Iowa, July 26, 1914.

JAN 2

VOL. XIX, No. 10. DECEMBER, 1914

JOURNAL
OF THE
WESTERN SOCIETY
OF
ENGINEERS

CONTENTS

The Work and Some Accomplishments of the Forest Products Laboratory, Madison, Wis. Howard F. Weiss.................... 933
Some Aspects of the Work of the Illinois Utilities Commission. Robert M. Feustel.................... 965
Coon Rapids Low Head Hydro-Electric Development on the Mississippi River Near Minneapolis. J. W. Link.................... 979
American Mining Congress. Report of 17th Annual Meeting...... 1016
Proceedings of the Society. Minutes of Meetings.................... 1019
Book Reviews 1021
Library Notes 1026
Membership 1028
Index to Advertisers.................... xxii

CHICAGO
Published Monthly, Excepting July and August, by the Society,
1735 Monadnock Block.

Entered as Second-Class Matter March 9, 1896, at the Postoffice at
Chicago, Ill., under Act of March 3, 1879.

Subscription Price, $3.00 per Volume of Ten Numbers.

50 Cents a Single Number.

Copyright, 1914, by the Western Society of Engineers.

WESTERN SOCIETY OF ENGINEERS

1735 Monadnock Block, Chicago, Ill.
Phone Harrison 945.

OFFICERS FOR 1914.

President .... E. H. Lee, Dearborn Station
First Vice-President .... B. E. Grant, Room 207 City Hall
Second Vice-President .... Ernest McCullough, 501 Monadnock Block
Third Vice-President .... G. F. Gebhardt, Armour Institute
Treasurer .... C. R. Dart, Room 700, 900 Michigan Ave.
Trustee .... J. G. Giaver, 1 year, 1417 Railway Exchange
Trustee .... F. E. Davidson, 2 years, 1448 Monadnock Block
Trustee .... H. S. Baker, 3 years, 402 City Hall

Past Presidents on the Board of Direction.

O. P. Chamberlain .... 108 So. La Salle St.
W. C. Armstrong .... 226 W. Jackson Blvd.
Albert Reichmann .... 208 So. La Salle St.

ELECTRICAL SECTION

Executive Committee

F. J. Postel, Chairman; H. M. Wheeler, Vice-Chairman
G. T. Seely .... 1 year
P. B. Woodworth .... 2 years
E. W. Allen .... 3 years

BRIDGE AND STRUCTURAL SECTION

Executive Committee

J. H. Prior .... Chairman
J. W. Musham .... Vice-Chairman
E. N. Layfield H. C. Lothholz I. F. Stern

HYDRAULIC, SANITARY AND MUNICIPAL SECTION

Executive Committee

W. D. Gerber .... Chairman
G. C. D. Lenth .... Vice-Chairman
W. W. DeBerard Douglas Graham Langdon Pearse

Secretary .... J. H. Warder

The Chanute Medals

The Board of Direction, W. S. E., desire to announce that the Octave Chanute Medals will be awarded for the most meritorious papers on Engineering subjects presented before this Society by members thereof during the year 1914.

Journal of the
Western Society of Engineers

VOL. XIX DECEMBER, 1914 No. 10

THE WORK AND SOME ACCOMPLISHMENTS OF THE FOREST PRODUCTS LABORATORY, MADISON, WIS.

Howard F. Weiss, Director.

An Informal Address Presented November 2, 1914.

It affords me great pleasure to be with you this evening. I have always felt that a closer contact between your Society and our organization would result in our mutual benefit. It was with this in view that I very gladly accepted an invitation to talk to you.

The topic of my address is the institution at Madison, Wisconsin, known as the Forest Products Laboratory. I wish to tell you what that institution is, what it stands for, and some of the things that it has accomplished in the four years of its existence.

America, as you all fully appreciate, is distinctly a wood-using nation. Her annual consumption of lumber is between forty and fifty billion feet. Expressing that another way, we use over three hundred cubic feet of saw logs per capita per year in the United States. England uses fifteen cubic feet. There we have the extremes of our great leading nations,—America with three hundred cubic feet and England with fifteen. In this country we have been cutting our timber approximately four times as fast as we have been reproducing that timber, which tends to a marked shrinkage in our timber supply with a consequent crippling of very important American industries.

Doubtless many of you have heard it stated by certain propagandists that the United States faces a timber famine in about fifty years. Personally I cannot reconcile myself to that statement, for two reasons. In the first place free land in the United States is practically all gone. As our country becomes more densely populated and we approach more and more the conditions abroad, the per capita consumption of lumber will decrease. As a matter of fact, we have already passed our maximum lumber output. Though I have not been able to get any reliable statistics, I feel that the per capita consumption of lumber will decrease at a more rapid rate than our population will increase. Another reason, a second reason, why I feel we need not fear a timber famine, is because we are learning more and more to utilize timber efficiently. You, gentlemen, in your own concrete constructions have already discovered means of using the same lumber over and over again. You build an eight or ten story building of concrete and you use simply enough lumber to make the forms for the first two floors. You are now making nails with double heads. You are using metal forms. You are standardizing all along the line. Such practice is going to result in a more efficient utilization of timber and a consequent decrease in the quantity required.

So I feel that we in the United States need not fear a timber famine. I do feel, however, that if our country is going to maintain the lead in certain of its great industries, it is absolutely necessary for us to exercise caution in handling our great basic resources of timber.

OBJECT.

The laboratory at Madison has as its object the most efficient utilization of timber. That means three things, broadly speaking.

FIRST. Finding a practical use for those species of trees now left standing in the forest because they at present possess little or no commercial value. Take the red gum; not more than fifteen or twenty years ago this was considered a valueless wood and was left by the lumbermen in the forest when they felled the cypress and other more valuable species. Now the red gum is one of our leading hardwoods, due to the fact that we have improved logging and kiln-drying methods. One of the largest hotels in this city is beautifully finished in red gum in Circassian effect. We still have in this country a number of woods that are in the same position now that the red gum was a number of years ago. Out in the West, in Montana and Idaho, there are millions of feet of larch—a beautiful wood—which we are not able to dispose of in our stumpage contracts. We have had to compel the lumbermen to remove the larch. They would not bother with it because it had certain inherent characteristics which could not well be eliminated, the chief being the difficulty of kiln-drying. The white fir which grows in California is now classed as a "tree weed." One problem then is to find a use for these varieties of trees which are left standing in the forests because they have little or no commercial value.

SECOND. Increasing the efficiency of utilizing those forest products already in demand, such as lumber, ties, poles, etc. I think the most specific example of this is what has been done in the preservative treatment of railroad ties. We use approximately 120,000,000 railroad ties in the United States every year, most of which go for renewals. The average life of these ties is seven years. By proper methods of preservative treatment, we can bring that life of seven years up to seventeen years—more than double it.

THIRD. Eliminating wood waste, both in the forest and in the mill, resulting from present operations. Only about fifty per cent of a standing tree is utilized. The other fifty per cent is wasted somewhere, either in the form of stumps, limbs, tops, slabs, edgings, shavings, sawdust or bark. In other words, only about fifty per cent of the tree is put on the market in a merchantable form. Of that fifty per cent there is still an enormous waste. For example, a vehicle or furniture factory will waste ten, fifteen, or twenty per cent of the lumber which they purchase, so that in the finished product really not over thirty to forty per cent of the wood as it grows in the forest is used. It is obvious that any industry which wastes that enormous percentage of its raw material will have a strenuous fight for its existence, and those of you who are familiar with the lumbering industry at the present time will, I think, agree with me that this industry is surely having a strenuous existence right now.

Not more than three months ago I went to the Pacific Coast and found sixty per cent of the mills closed down, and more were closing down every day. Of course, we are facing now rather unusual conditions. In spite of this, there are certain broad, basic, fundamental changes that are occurring in regard to the utilization of timbers, which neither lumbermen nor the Government nor any one else can stop. They are in line with the progress of civilization and I believe it behooves the lumbering industry to look at these things in a much broader way than they have in the past. Lumbermen have frequently taken an attitude of opposing these changes. Some of them even believe we ought to have wooden sidewalks. Their tendency is to fight progress all along the line. It is characteristic, I think, of Americans to swing from one end of a pendulum to the other. In the car proposition we have swung to an all-steel car. The last time I went to New York they handed me cigars in a steel box. I believe we sometimes carry things to extremes, when a half-way course would be much better. It is squarely up to the lumbermen to realize that these broad changes are occurring and to modify their business to conform to them. For example, the fibre box is here to stay. The lumbermen are not going to put the fibre box industry out of business. The fibre box, however, is not adapted for shipping pianos, and there is a limit to its use. There is a limit to the use of the wooden box. In my opinion, that man is going to succeed best who finds out first what those limits are.

I believe you now have a general view of the types of problems which our institution is attacking—three broad attacks, aimed at better efficiency in utilization and merchandizing.

ORGANIZATION AND FIELD WORK.

Just a word in regard to the personnel and organization of the laboratory. It is maintained by the United States Government through its Forest Survey in coöperation with the State of Wisconsin through its University at Madison. We have been building up the equipment in the institution for the past four years and now have about all the machinery necessary to study wood from a chemical, mechanical, pathological, or other standpoint. We have built up a staff of approximately ninety-five people, most of whom are graduates of our American universities in chemistry, engineering, botany, pathology, physics, or some other special line which we need.

I want to mention two points of policy, because I feel that a number of you gentlemen may be engaged in consulting work, and I have frequently received letters to the effect that our Government was taking a too paternal attitude, and that it was dabbling into our industrial life to the extent of preventing many from making a respectable livelihood. So I want to make these two points of our policy perfectly plain to you.

The first point is that the laboratory does not work upon any problem which is of exclusive benefit to individual companies. We made a series of tests on packing boxes in coöperation with the Interstate Commerce Commission. After we made these tests we were deluged with letters from various box makers all over the country, who wanted us to make tests on their types of boxes. They felt very much injured when we told them that we could not make those tests. We are not in the business of making tests to find out whether Mr. Jones' box is better than Mr. Smith's box, etc. If they want tests of that nature made, they will have to go to some consulting concern and have them made, or make them themselves. We are dealing with generalities, not with specific instances.

Another point which is sometimes difficult to understand is that we do not, as a rule, give a direct reply to certain inquiries. A man will write, "I have 10,000 telegraph poles that I wish to treat with some kind of a wood preserver. How about this preservative; do you recommend it for our use?" We cannot tell that man yes or no. All we can do is to answer him in an indirect way by sending him the data that we have on this particular preservative, together with other makes of preservatives and let him draw his own conclusions. This is not a very satisfactory way to answer an inquiry and it is not the way you gentlemen would answer an inquiry. You would say, "Yes, use this," or "Don't use this," and you would have your reasons for it. We cannot do that.

In order to handle this broad field of problems assigned to us, we have divided our laboratory into a number of technical sections. We have five main sections of a technical character. We call them Timber Tests, Timber Physics, Wood Preservation, Derived Products, and Pulp and Paper.

Figure 1 represents the rear end of our building, which looks more businesslike than the front view. You will note that there is a side spur of the C. M. & St. P. Ry., a large derrick for unloading the logs, some railroad ties in our storage yard, and a shed in which we season our lumber.

With reference to our carpenter shop, there is nothing unique about it, but there is a certain feature connected with it that might interest you. Wood is something which has been created by nature. It is something which we cannot make ourselves. Consequently,

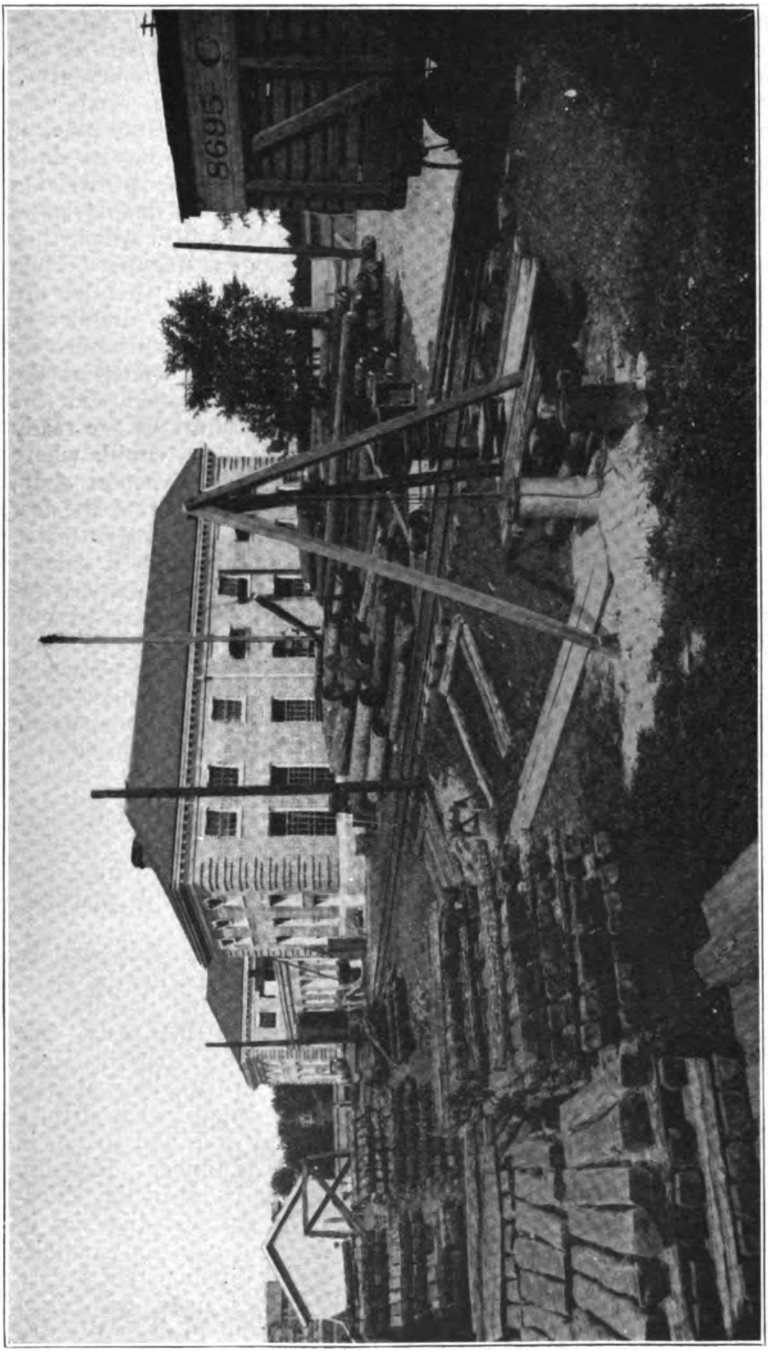


Fig. 1.—View of Forest Products Laboratory.

there is great variation in the quality of timber, and for our purposes we have to know definitely just what kind of timber we are experimenting with, under just what conditions that timber grew, what part of the tree the specimen came from, and so forth. So in making a test, say on white oak or on hickory or white pine, or any other specie that grows in our country, the first thing we do is to send one of our men to the territory where that timber grows. On his arrival he selects five trees which represent average quality, takes photographs of them, and notes the condition of soil in which they grew, their exposure and certain other ecological factors. Then the trees are felled, and sawed into logs. The ends of each log are painted. The north side of the log is marked and the number of the log is painted on each small end. The logs are then hauled by team or other means to the railroad, where they are loaded on the cars and shipped to the laboratory. They are unloaded with the derrick shown in Fig. 1, and are kept in storage until we are ready to test them. They are then passed through our sawmill, where they are sawed into planks, then they go to the carpenter shop, where they are cut to the exact size desired and then into the test specimen, according to what sort of analysis we are going to make.

We find that this procedure is necessary, although it sounds like unnecessary detail. It sounds, perhaps, like too ultimate a refinement, but experience has taught us that unless we know exactly under what conditions our test specimen has grown, we can tell very little about what the test specimen shows. Red oak grown in Arkansas is entirely different from red oak grown in Indiana. Douglas fir grown on the Coast is entirely different from Douglas fir grown in Utah, although they are identically the same specie.

TIMBER TESTS SECTION.

The first mentioned section—that of timber tests—undertakes to determine the mechanical properties of wood and of the products made from wood. We have five 30,000-pound testing machines, one 100,000-pound Riehle machine, one 200,000-pound Riehle machine, and an impact machine.

As to some of the work which has been done in this section: The broad, basic problem has been to determine the mechanical properties of all of our important American timbers, and thus far we have covered about 100 species and made over 150,000 tests. We now have a pretty good working knowledge of the strength of our most important American timbers. What we are working at now is to find out what effect altitude has on the strength, what effect a sandy, loamy soil has as compared with a clay soil, and so on, in order to work out all the variable mechanics of timber. Recently one of our men started a survey of the building codes of the different cities. We have found that there is the greatest diversity in the allowable stresses of the different cities. One city, for example. will allow a working stress for yellow pine of 900 pounds per square inch. Another city, located less than 100 miles away, will allow 1,800 pounds for identically the same specie and grade. We are trying to work with these different cities to bring about a standardization of stresses, a standardization of quality of timber, a standardization of grade; rather a difficult problem, but I believe it is something which should be done for the interests of both the cities and the lumber manufacturers.

Another piece of research we have under way is to test the mechanical efficiency of built-up beams, of joints, and so forth, as compared with natural beams. For example, a four by eight as compared with two, two by eights nailed together. I have been rather surprised at the results thus far, as I felt a built-up beam was stronger than a solid beam, but these tests do not indicate such is the case. We are finding the nail-holding strength of wood at different points from the ends and the efficiency of different types of bolts, washers, and so forth.

We recently completed a series of tests on barrels, and, strange to say, a barrel had apparently never before been tested. We did not know how to go about testing a barrel. We wrote to all of the large cooperage manufacturers and asked them how they wanted the barrels tested. They said, "That is what you are there for." So we devised a series of tests which we thought would most closely duplicate the various strains a barrel would be subjected to in carrying its contents. We had shipped to us, in coöperation with the Bureau of Explosives, a carload of whiskey barrels, the finest kind of whiskey barrels I have ever seen. They all came to the laboratory with my name burnt in the end. We were not permitted by the cooperage people to drive the hoops on those barrels because they said we did not know how to drive hoops and that was a trade by itself. Consequently, they sent their own expert from St. Louis, to drive these hoops, and then we started in testing the barrels. To cut a long story short, we found that the barrels failed in an entirely different place from the one the manufacturers thought they would or from where we thought they would fail. They shipped the barrels to us with what is called short "chime." (The chime is the part that sticks out beyond the head.) When we put an internal water pressure on these barrels water spurted through the chime. Consequently the longer chime used in standard practice was better than the shorter chime used in making these test barrels. Furthermore, the barrels burst in the heads. By arranging the hoops in a different way from what they had them, placing them nearer the center of the barrel, and by putting in a head which was one and one-half times the thickness of the staves, we made a barrel that was 25 per cent stronger than the best barrel they shipped to us, and it required a less amount of wood. We simply put more wood in the head of the barrels and took it out of the staves, and spread the hoops on the barrel in order to more evenly reinforce the staves.

Another interesting fact about these tests was, when one dropped a barrel on a platform it would "spring" and a little water would spurt out, but immediately it would be perfectly tight. With a metal barrel, there is but little "spring" and with a puncture the water keeps on running out.

A feature I want to call to your attention, in connection with the effect of moisture on the strength of wood, which probably a good many of you already know, is that as the moisture content of wood increases the strength decreases until a certain point is reached, after which increasing the moisture content has no effect whatever upon the strength of the wood. That "point" was discovered by one of our men, Mr. H. D. Tiemann, and is called by him the "fibre saturation point." In other words, it is a point where the wood fibres have taken up so much water that the addition of more water simply goes to fill the cell cavities. Hence, after wood takes up a certain amount of moisture, no effect whatever is had upon the strength by adding more water. The fibre saturation point is more or less constant in the different species and ranges from about 20 to 30 per cent. Old timber tests made by the Germans show these moisture strength curves in an entirely different way from what I have shown you.

The railroads of the United States have had great difficulty in getting shippers to properly pack their products; the result has been that claims against the railroads for goods damaged in transit have been enormous. This matter was taken up by the Interstate Commerce Commission, through the Bureau of Explosives, and we made quite a large series of tests on packing boxes. Figure 2 shows one method of testing wooden boxes. You will note the character of the failure. We found that a box made with a very small quantity of wood wound with wire is one of the toughest varieties of boxes now put on the market. These tests have been used by Colonel Dunn in drawing up specifications for shipping containers to be used by the Interstate Commerce Commission.

In illustration of some of our work, consider two hickory wheel spokes, one is "red hickory," and the other "white hickory." In other words, one spoke comes from the heartwood, the interior of the tree, and the other comes from the sapwood or the exterior of the tree. All the old specifications for hickory spokes, mallets, and so forth, excluded the red hickory, it being supposed that this variety of hickory was not as good as white hickory. So in coöperation with some of the vehicle associations we made a large number of tests of spokes and found that the discrimination against the red hickory was largely unwarranted; that if one had red hickory which was as dense as the white there was very little difference in the quality of the spokes. We took this matter up with the Isthmian Canal Commission and they changed their specifications for pick handles, shovel handles, and similar products to include a certain amount of red hickory. This has resulted, in turn, in decreasing very materially the waste in cutting this valuable wood. Red hickory is now permissible in a majority of hickory specifications, whereas not more than ten years ago it was rigidly excluded.

I believe these examples will give you a general idea of what

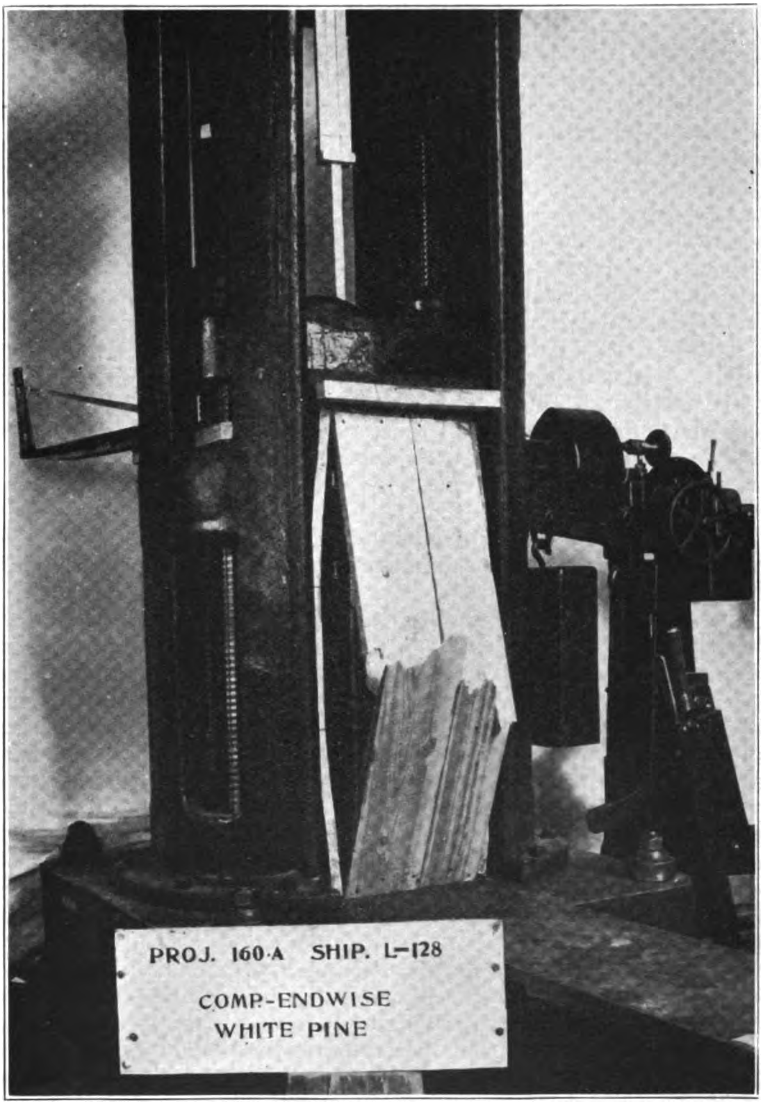


Fig. 2.—Method of Testing Boxes.

we have been doing in our section of Timber Tests in studying the mechanical properties of wood.

TIMBER PHYSICS SECTION.

In the section of Timber Physics we study the physical properties of wood; that is, the length of the fibres, the structure of wood, moisture, and heat transmission in wood.

From the physical standpoint our American timbers are divided into three main groups according to the "holes" or pores which they contain. The first group is known as a non-porous group, in which are included all the pines,—the conifers. That is, these woods do not have little pores or "holes" in them. The second group is what is known as a ring porous wood. The pores occur in rings, and hence the name ring porous wood. There are peculiar walls inside the pores. These walls are cells which grow out from the sides of the vessels, ultimately plugging them. They are known technically as "tyloses." Red oak looks like white oak, but it does not have these vessels. You can quite readily blow through a piece of red oak four or five feet long. But it is absolutely impossible to blow through a piece of white oak because of these tylose partitions. Tyloses make possible the use of white oak for barrels to hold liquids, and prevent this same use of red oak unless by some artificial means the pores are plugged.

The third group is known as the diffuse porous wood, so-called, because the pores are diffused uniformly throughout the entire width of the ring.

As to some of the researches we have under way in this section: There has been a great deal of controversy on the part of the manufacturer and buyer as to how to tell long leaf pine from short leaf pine, and short leaf pine from loblolly and loblolly pine from Cuban pine, and so forth. One of our men has been trying for the past two months to determine a positive means of telling short leaf from long leaf pine. Go to an average lumberman, hold up a piece of wood and he will give you at once a name. Ask another lumberman about that same piece of wood, and the chances are he will give you an entirely different name. So far, it has been absolutely impossible to distinguish short leaf, long leaf, or loblolly pine from each other, unless you had typical specimens, because they so merge into each other. We have known no distinguishing characteristics. I sent our representative to get samples of the Southern pines from old trees and young trees, from the base of the tree and the top of the tree, from fast-growing and slow-growing trees. He has been working with a microscope trying to find some positive means of identifying these woods. He identified the trees from which he took the wood in the forest, which is a simple thing for a botanist or a lumberman to do, but to identify the wood is quite different. He has already found what he believes are certain distinguishing characteristics which apparently are constant. One of them is the arrangement of the pith; the other is in the width of the medullary rays.

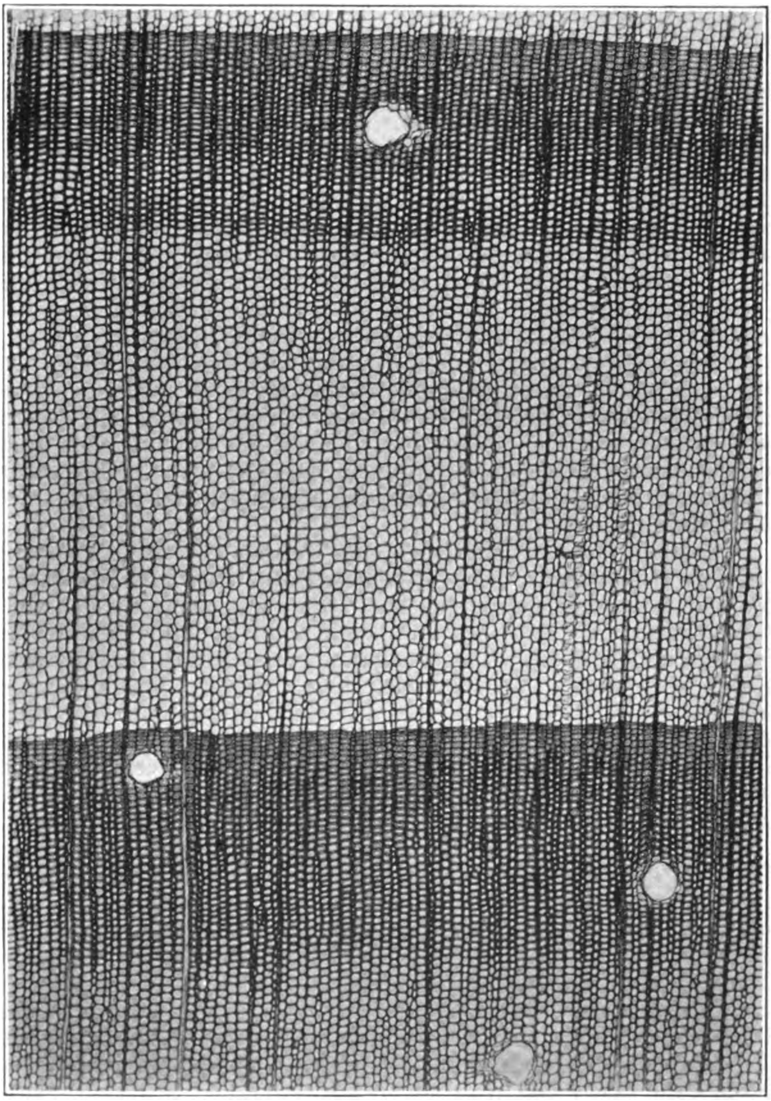


Fig. 3.—Photomicrograph of Cross Section of Shortleaf Pine (Pinus Echinata) × 50.

These determining factors will be of value chiefly in court cases. One could not very well carry a microscope around in a lumber yard and look at the wood in order to find out what it is. I believe we have solved the identification of the wood of the Southern pines and shortly we will issue a publication on it.

Another thing which we are developing in this section is a little book to be given to tie inspectors to slip in their pockets, so they can learn how to distinguish between the different kinds of ties. I recently ordered 4,000 ties from one of our Western railroads. I asked for two varieties of wood,—maple and red oak,—2,000 ties of each. I got eight species, among them being butternut and hemlock, and these ties, understand, were passed upon not only by the ordinary run of inspectors, but by the chief inspector of that railroad. Furthermore, a lot of those ties were not even up to grade, irrespective of species. We found approximately 500 ties absolutely unfit for use. That is what happened in a 4,000 tie order. That is what happens every day. We are putting into this book, which I say will be a handbook, some simple means for a tie inspector to tell maple from beech, or from birch, and so forth, using only a hand glass magnifying to five diameters. I think this publication is going to help considerably—at least the tie men tell me it will—toward eliminating much controversy between the buyer and manufacturer of railroad ties.

Another problem handled in this section is that of removing moisture from wood or what is commercially known as kiln-drying. We had a piece of eucalyptus board that was perfectly flat when it was sawed. We let it lie on the table and it actually "walked off" the table in drying out. The eucalyptus grows so fast that the wood is full of stresses. You can hear logs "crackle" like a piece of breaking glass. It is one of the most difficult woods to dry, but a beautiful wood after it is dry.

Figure 4 is a cross section through a dry kiln developed by one of our men, that works very satisfactorily. He has taken out two patents on this kiln in the name of the public so that any American who wants to use it can do so without the payment of royalties. The cross section of the kiln shows two vertical walls, spaced about eighteen inches from the sides, with a series of baffle plates, and a row of steam pipes, together with a trough to catch the water. The unique feature of this kiln is the circulation, which is maintained by means of a spray of water. Running along the top of the kiln is a pipe in which are inserted, every two or three feet, a spray nozzle, which shoots a fine spray of water into the chamber. The water runs into a trough and then is picked up by a pump and recirculated through the kiln. The great advantage of the kiln is that it is absolutely closed. It makes no difference whether it is hot or cold outside, whether it is dry or wet, for you can control, absolutely, the temperature, the humidity, and the circulation. These are the essentials of a good kiln and any kiln which controls these three things at all stages of the process will successfully dry wood. In operating

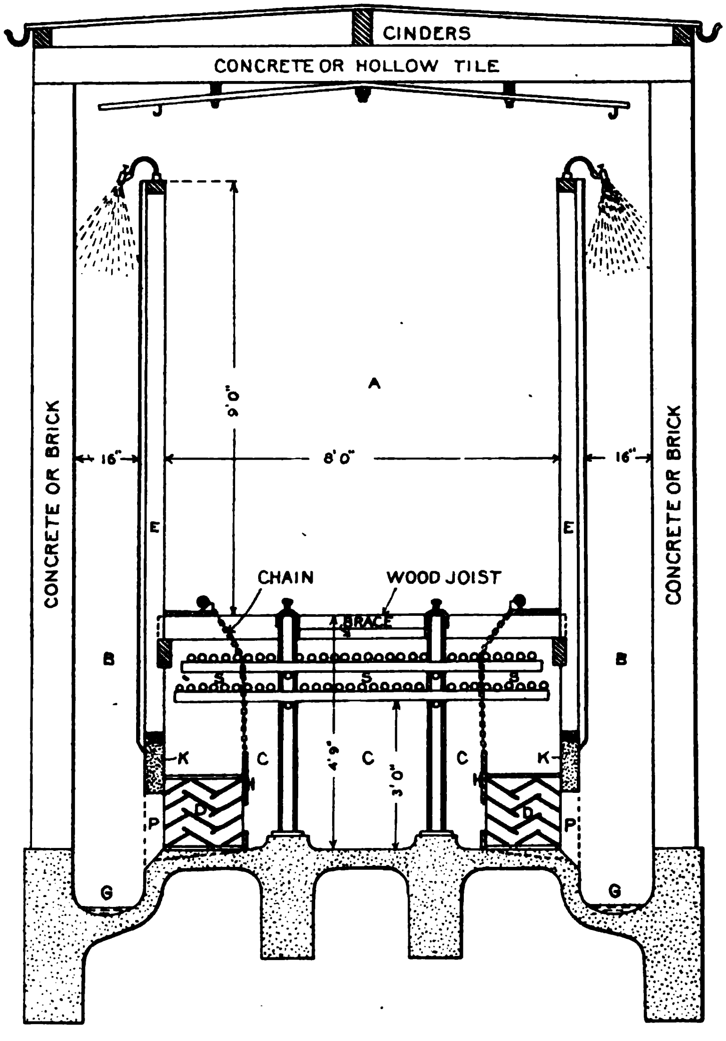


Fig. 4.—Section Through Forest Service Humidity Controlled Dry Kiln.

the kiln we pass steam through the coils to bring the temperature up to 150 or 160 degrees Fahrenheit. Hot water is then sprayed down into the chamber. After a while the pile of lumber, which is placed on the track, is heated to the center. This does not dry the lumber; in some cases it is actually soaking the lumber with water; what it is doing is simply heating it. We keep the lumber in the kiln until it is heated clear through to the center. When that is accomplished we change our thermostat valve and begin lowering the temperature of the spray water. It starts, say at 170 degrees, and is gradually cooled until nothing but cold water passes through the nozzle. By this means, keeping the steam in the heating coils constant or raising it at the end of the operation, we can dry lumber down to three or four per cent or less of moisture. The kiln has been very successful in drying woods. In fact, it has succeeded in drying a number of woods which the manufacturers heretofore have not been able to use.

A piece of oak wagon rim was dried in a certain commercial dry kiln and the honeycomb effect was very marked, because it took the moisture from the outside, in. In our system of drying—and some other commercial systems do the same thing—we take the moisture from the inside, out. The same kind of wood, kiln dried in our kiln, manifested no signs of checking or honeycombing. What we did with this oak is something that we have also done with hickory, with the Western larch, and with the Western red cedar. We are now working upon a method of properly kiln-drying red gum. All this work is being done by Mr. H. D. Tiemann.

WOOD PRESERVATION SECTION.

As the name implies, the section of Wood Preservation is devoted entirely to studying methods of preventing the rotting of timber. In the last year and a half we have expanded to include methods of preventing destruction of timber by fire and the destruction of timber by mechanical causes, such as spike cutting, rail cutting, and so forth. One of our common wood-destroying fungi, is called mycelium. The tie is permeated with little, fine, root-like hairs going through the wood, which, after they develop in the wood to a certain degree, come to the surface and form a mass known as the fruiting body. Underneath this hood are little gills which hang down and it is on them that the seeds, or spores, are formed. These are microscopic in size. They are like dust particles, easily picked up by the wind. When they alight on timber they fasten to it and propagate.

Figure 5 is a longitudinal section of wood. You will notice how the cells are arranged. The black spots are called "pits." It is through them that the sap gets from one cell to another. These cells are the medullary or ray cells. The lines are the threads, roots or mycelia of the fungus. Up in the medullary cells, where there is quite an accumulation of starch, you will notice the density of mycelia. After a while the mycelia become so numerous that the

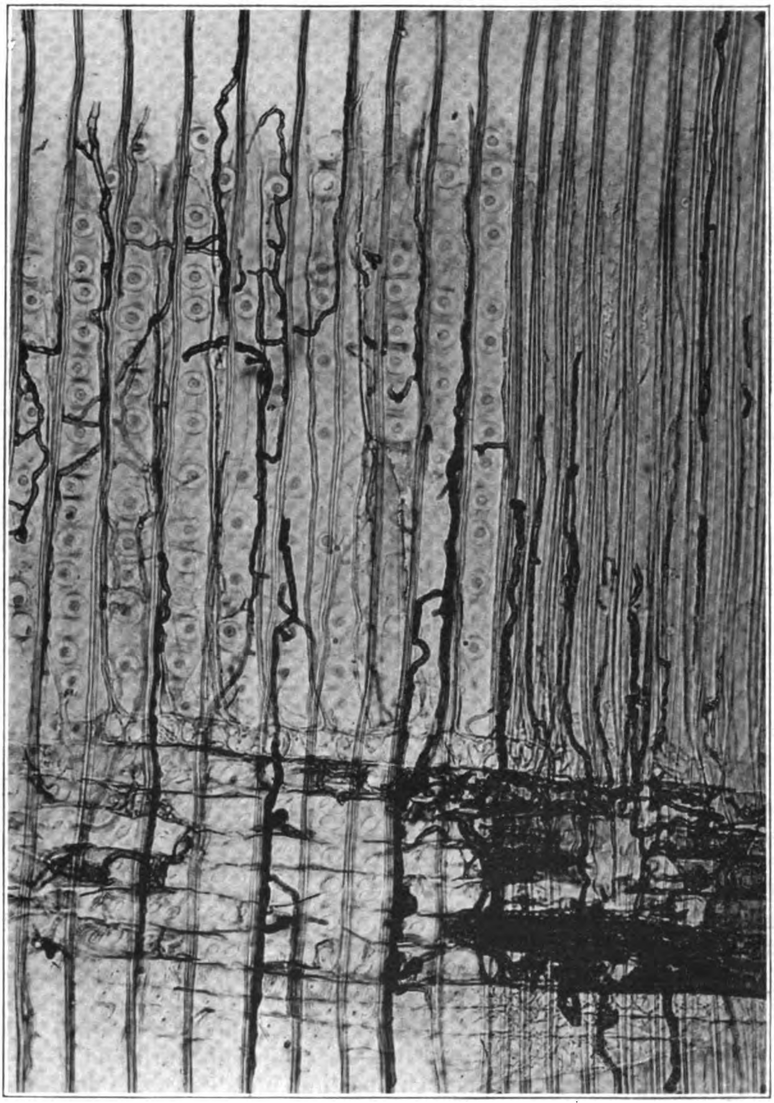


Fig. 5.—Photomicrograph of Radial Section of Shortleaf Yellow Pine (Pinus Echinata) × 250, Showing Fungus Mycelium.

wood cells no longer have any strength. Their "life" is gone, and the wood is then what we call rotted.

One series of investigations we have under way in the section of Wood Preservation is to find out the preservative value of a large number of products now put on the market as wood preservatives. We have tested about thirty-five of them. I wish to comment at this point on a peculiar condition which, I think, ought to be taken seriously at this time. Apparently those engaged in commercial treatment of timber have not seen fit to do so. We, and other American investigators, together with some Austrian and German investigators, agree that the toxicity of coal tar creosote and zinc chloride, that is, their ability to kill fungus, is practically the same. In other words, one-seventh of a pound of creosote injected into wood per cubic foot will keep that cubic foot free from attack, provided you can keep the creosote in the wood. In commercial treatment we ordinarily put in at least eight pounds; some people go as high as ten, and in paving blocks as high as sixteen pounds. Suppose we use eight pounds,—theoretically we are putting in fifty-six times as much creosote as is necessary to keep that wood sound. Look at the specifications for the treatment of timber with zinc chloride and what do you find? You find they call for one-half pound injection, or about four times as much as is theoretically necessary. If creosote is commercially better than chloride of zinc, why this great difference? If you were building a bridge and had a girder on the north side and one on the south side, you would use the same factor of safety for both. Why have fifty-six times as much creosote as is theoretically necessary, and only four times as much zinc chloride as is theoretically necessary, if, as a number of engineers will argue, creosote is the superior product.

A number of creosoting companies have written to me within the last few weeks and said, "We are obliged to shut down as we have no creosote." The United States uses 110,000,000 gallons of creosote in a year, about 70% of which comes from abroad, and, of course, the foreign supply is now shut off. Our advice to these companies has been to use less creosote, treat the ties with two pounds to the cubic foot, or treat them with zinc chloride instead of shutting down the plant and giving no treatment at all. The dangerous thing, however, in advocating treatment of wood with only two or three pounds of creosote to the cubic foot is this: If you tell the average treating engineer to do that, he is likely to put in two and a half pounds, in the same way that he does eight or ten pounds. Hence, only one thing can occur, and that is failure. The essential thing is to get the creosote clear through the wood if possible. There is no advantage in putting more creosote into ties than is necessary, because if your tie wears out, you remove it from the track and burn up the creosote in it as well as the tie. The thing to do is to produce the tie failure from mechanical causes and from decay at approximately the same period.

We have coöperated with several coal companies in the East, notably the Philadelphia & Reading, and placed in their mines a large quantity of timber, treated in different ways. Untreated wood —perfectly sound timber—in those mines will be completely rotted in about eighteen months, but this treated timber has remained perfectly sound. It has been in use now eight years. The timber treated with zinc chloride shows the same results. It is perfectly sound at the end of eight years. The only failures we have had were caused by crush or "squeeze" in those timbers.

Untreated piling, when driven in salt water inhabited by shipworms, is subject to severe attack from that source. In some cases the piling is completely eaten off at the water line. It is frequently destroyed in two months, when ordinarily it lasts from two to three years along the Atlantic Coast. The teredo is very destructive and a difficult agency to combat. We are endeavoring to determine the best method of preventing this kind of attack. These shipworms are found from New York City south down the Atlantic Coast. They are most destructive along the east coast of Florida, and the Gulf of Mexico. On the Pacific Coast they are found from Alaska, south. Creosote is an efficient preservative to use, provided it is used properly. In order to discover if some other preservative would not be just as good or better than creosote we have been experimenting with certain inorganic salts. Our test specimens are about six inches in diameter and two feet long. A hole is bored through these, after which they are heated and bolted to a zinc plated iron ring, about three feet in diameter. These rings are then lowered into the salt water. There are three rings on each chain, arranged from mud line to high tide.

There is one common cause for the failure of creosoted piling, —namely, improper treatment, due to insufficient specifications and hollow material.

A very efficient means of prolonging the life of piling from these teredos or shipworms is by means of a cement casing. It is made in two parts so it can be placed around the pile, and the two parts are then locked with a wooden key. The beauty of this kind of treatment is that you can put such casings on to your piers in case you find they are being attacked. They will absolutely keep out the teredos. One objection to their use is, if there is much débris floating in the harbor it is liable to be thrown against the casing and crack it. As soon as that happens, no matter how small the crack may be, these little teredos will get at the wood.

The treatment of wood used for paving purposes, is something which is perhaps more familiar to you. In this city you had a strong agitation a few years ago over what was called the "black plague." Tar would come to the top of the pavement and stick to the shoes of pedestrians, who, in going into the stores and their homes, would track this tar in after them. Your experience was like that of a good many other cities. We tried to find out what caused this "bleeding," and, if possible, to discover a means of overcoming it. After four months of work in the laboratory we found what we think is the cause and a proper method of overcoming it. It is our policy not to consider any experiment finished until it has been demonstrated on a commercial scale. In order to demonstrate the practicability of our laboratory results we coöperated with Kansas City. We could not coöperate with Chicago because we found so many varied interests here, which wanted to "climb on board" our test that they "gummed the experiment." We would have had about eighteen different kinds of treatment if we ran the tests in Chicago. So we went to Kansas City. We had just finished laying a pavement near the new terminal there, part of which is built according to the standard specifications of Kansas City. The other half is laid with blocks treated in exactly the same plant, with exactly the same oil, but with the modified treatment worked out in our laboratory. These blocks were perfectly dry when put down. Of course, as bleeding does not occur in the winter we will not know whether our results are conclusive until next spring. What we did was this: We felt that the chief cause of bleeding was the air contained inside the blocks. In other words, in order to satisfactorily treat paving blocks it is necessary to get the air out before you put the oil into them. So we steamed the blocks. We steamed them green in order to get out more of the moisture. We steamed them dry in order to have them take up moisture and assume a maximum volume. The treatment of green blocks is perhaps better than the treatment of dry blocks. Then after we steamed them, we pulled a strong vacuum in the retort and took most of the air out of the blocks. After the air was exhausted we filled the cylinder with the preservative. When the desired absorption was obtained—we used sixteen pounds, I think—the cylinder was drained and a final vacuum drawn. The final vacuum was to dry and clean the blocks. When we used mixed tar and creosote we steamed the blocks at the end of the treatment in order to clean them. One or two commercial wood preserving companies are using this method of treatment.

Another problem connected with wood blocks is in regard to the uniformity of the treatment. A piece of long leaf pine paving block was creosoted with sixteen pounds of oil to the cubic foot. You will find that a good many paving blocks are treated in that manner. Another block was also treated with sixteen pounds of oil to the cubic foot. I believe I told you that summer wood is dense —a good deal heavier than spring wood. Ordinarily one would think that if the summer wood is dense and heavy it will be the last place for the oil to penetrate, but it is the easiest place for the oil to penetrate. The reason is that in the summer wood there are what are called "resin ducts" and the oil goes right through them. A block having wide rings, will not be nearly as serviceable as one having narrow rings.

We have coöperated with the American Telephone and Telegraph Company in finding practical ways of treating poles. We have treated in various ways several thousands of poles and have set them in different parts of the United States. There is a test line running from Omaha to Denver, another from Warren to Buffalo, and another from Poughkeepsie to New York.

One method is brush treating. The preservative is simply painted on the pole. Our results thus far indicate that brush treating will increase the life of the pole about three years. Some of these poles were treated by the open tank method. That is, we set them into an open tank and boiled the butts in oil and then let the oil cool. In this way it soaked through the sap wood and a penetration of one-half or three-quarters of an inch was secured.

So far we have found no open-tank butt-treated poles decayed. Apparently this method is going to be a very efficient means of prolonging the life of poles. Another interesting point brought out by these experiments is, that a pole placed in sandy soil should be brush treated in a different way from one placed in clay soil.

I told you that in the wood preservation laboratory we had gone into the problems of fireproofing wood. As you know, a number of cities have already passed ordinances prohibiting the use of the wooden shingle. Some cities have prohibited the use of wooden trim of a certain description. This agitation has gradually spread until the markets for wood are rapidly becoming narrower. In other words, the demand is rapidly falling off. We undertook to find out whether or not it was possible to impregnate wood with certain chemicals in order to make it sufficiently fire resistant to meet the requirements of the building laws and the Underwriters. We tested a great many paints applied to shingles but thus far have not succeeded in getting very good results from the paints, although they do make the shingles quite fire resistant. The theory upon which we have been working is to impregnate the wood with certain fire resisting compounds. For shingles, it must be a compound which is insoluble in water. The best treatment we have thus far discovered is one in which zinc chloride is forced into the wood, followed by a second injection of borax. These chemicals form zinc-borate, which is insoluble. We have soaked and burned these shingles and find the compound is really permanent. Figure 6 shows a piece of Western red cedar shingle which was tested in our inflammability apparatus. The flame was directed at it for twelve minutes. Note all that is left of the shingle. Here is the same shingle impregnated with the zinc-borate treatment. It did not burn at all, but simply charred. We have taken out a patent on this process. In the meantime, we are working to still further develop this treatment. What we are doing for shingles we are doing for wooden trim and other products where fire is considered a hazard.

DERIVED PRODUCTS SECTION.

In the section of Derived Products, chemistry is used as the chief means of solving the utilization of wood waste.

I want to tell you something about our wood distillation laboratory, because we have just finished a piece of research in it which, to my mind, is one of the best that the laboratory has turned out.

In his tests on the destructive distillation of wood, Mr. R. C. Palmer found that if the temperatures were kept low, that is, if we applied the heat at a slow rate until the exothermic reaction began, a larger yield of alcohol and a larger yield of acetate of lime was secured than if the distillation were made in the usual manner. We then coöperated with a chemical company in Michigan to verify these results on a large scale, and Mr. Palmer spent two weeks watching how this company built the fires and how they "pulled" the retorts. The second week he had them use a like quantity of wood for fuel at low temperatures and bring the temperature up gradually to the exothermic reaction. The results were yields of twenty-five per cent more wood alcohol and ten per cent more of acetate of lime than they had gotten theretofore. That meant, according to the general manager of the concern, a net saving to his company alone of $30,000 per year in operating expenses.

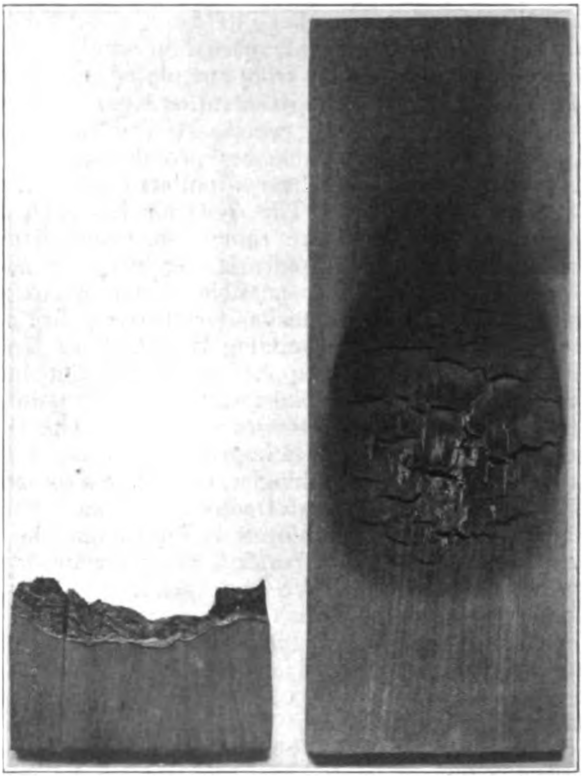


Fig. 6.—Treated and Untreated Shingle Burned.

I think this is one of the cleanest cut pieces of practical research that we have yet turned out, and I hope before a year goes by we can announce similar discoveries.

Another research now going on in the section of Derived Products is one which many people have tackled but in which very few have made progress, and that is the production of grain alcohol from wood waste. We have built an apparatus, mostly made in Germany, to carry on these researches. Our results to date have enabled us to turn out 22½ gallons of 190 proof grain alcohol to the ton of sawdust.

The basic principles of this process have been known for almost a century. It consists simply in treating wood with acid and steam. Such treatment breaks up the cellulose and forms sugars, some of which are fermentable. These sugars are washed from the sawdust, neutralized with some agent, and concentrated. Then into this syrupy mass yeasts are "planted." We have been using beer yeast, but we are now using rum yeast because we find it works better. The yeast converts the sugars into alcohol, which is then distilled off.

The United States leads all the nations of the world in the production of turpentine and resin and practically all of the turpentine and resin comes from the long leaf pine woods in the South. The old method of gathering consisted in chopping a hole or "box" at the bottom of the tree. Then a workman took an instrument with a big iron weight on one end and a sharp chisel effect on the other and gouged out a strip of wood about one inch thick. Cutting a big hole at the bottom of a tree, of course, very materially weakens the tree so that it is subject to destruction by wind blows, which cause an enormous waste of material.

The Forest Service has, with the coöperation of Dr. Herty, experimented with an improved method of collecting oleoresin, known as the "cup system." You will notice in Fig. 7 that no "box" is chopped in the tree, but a porcelain cup takes its place. Note the flow of resin into this cup. This method of turpentining has resulted in increasing the production of oleoresin twenty per cent, at the same time raising the grade. We are still working, trying to perfect this system. Such a great injury to the tree is unnecessary. When a pine tree is wounded there are formed at this portion a lot of secondary resin ducts. These ducts secrete the resinous material in order to protect the wound and keep out the fungi. If an inch of wood is removed every time the tree is chipped many of these little ducts are also removed and the tree has to consume energy and make them over again. If only a quarter of an inch is removed an even larger flow of oleoresin than before is obtained. So what we are trying to perfect is a "fool proof" tool which will go into the tree only to a certain distance, no matter how hard it is hit.

When the Frenchman taps pine trees he takes a long pole, sticks the toes of one foot around the pole, and those on the other foot in the bark of the tree, thus balancing himself. He climbs up that pole and makes a thin, narrow streak in the tree and hangs a little cup in it. It will be a very serious thing if our yellow pine is depleted, because we are almost entirely dependent on this tree for turpentine and resin. Our investigators have found, however, by experiments in California and Arizona, that about seventy per cent as much oleoresin can be obtained from the Western pines as from the Southern pines in Florida.

PULP AND PAPER SECTION.

The fifth technical section is the Pulp and Paper section. The paper industry is one of the most important which utilizes wood. Our Wausau laboratory is equipped with a 500 horsepower motor to grind various kinds of woods to pulp with the idea of finding out just what were the most efficient methods of grinding. We have completed that work now as the result of three years of research. We know definitely just what happens when you vary one of the variables of grinding. We know definitely what are the best conditions of grinding. In fact, we did such a good job that when the Canadian Government decided to build a Forest Products laboratory

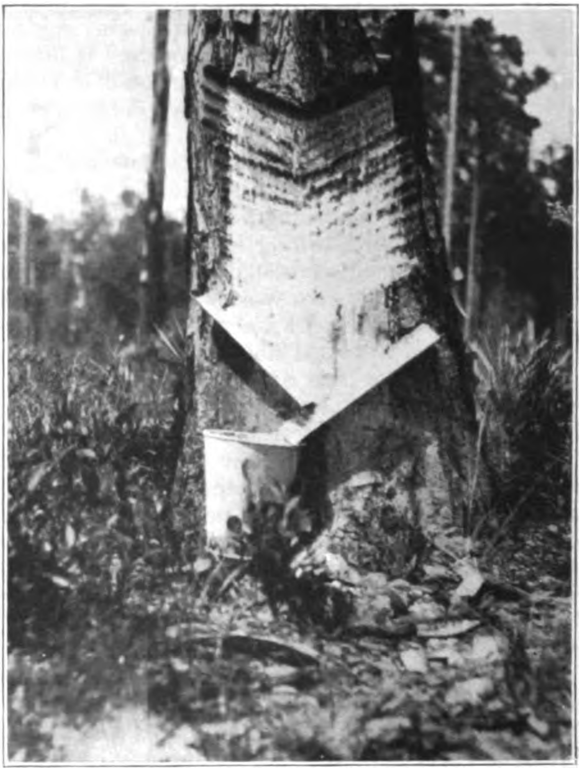


Fig. 7.—Naval Stores Gathering Oleoresin.

of its own, this was the only line of research they left out, because they said there was nothing more important to investigate. These researches are coming out in the form of a Government bulletin. They should be published about the first of the year and they ought to be of immense value to manufacturers of wood pulp, because many of them are throwing too much horsepower into their pulp and in other ways operating extravagantly.

We also undertook to find out whether it was possible to make a satisfactory sheet of newspaper from woods other than spruce—spruce now being a scarce timber in the Eastern United States and becoming scarcer all the time. They pay $11.00 to $12.00 a cord for it even now in Wisconsin. The newsprint industry has been largely driven into Canada. We found ten woods which grow in this country admirably adapted for the manufacture of newsprinting paper, and in accordance with our general policy of testing, we ran the pulps from these over the little paper machine in Madison and then coöperated with a commercial paper company and made several tons of pulp on a large scale. These pulps were manufactured into newsprint paper. The rolls of paper so made were then shipped to the *St. Louis Republic* and to the *New York Herald* and several hundred editions of those papers were printed on them. So, as a result of these tests, I think we need not fear for the extinction of spruce, because we have other trees to use which apparently yield paper as good as spruce.

In the paper industry, a sulphite digestor is used in making pulp. This is the sulphite process.

In addition to these researches, we are working on the problem of making wrapping paper from Southern pines. This country now imports large quantities of this paper, from Norway and Sweden, or did before the war started. Our researches lead us to believe that we can make from our own timber sheets of pulp which are equally as good as the pulp which we obtained from abroad. It is our hope that these researches will help to build up in the South a firmly established pulp and paper industry. In fact, the ultimate object of all our work is to build up in our own country, industries which will make us absolutely independent of all foreign countries, so the United States will become a truly self-supporting nation. Furthermore, it should not only become a self-supporting nation, but a large exporting nation.

DISCUSSION.

B. E. Grant, M. W. S. E. (chairman): Last August I was in Madison and had the opportunity of going through this laboratory and Mr. Weiss has told you of a few of the interesting things that I saw there. I was greatly impressed by the extent and diversity of the work done in the laboratory, also with my ignorance of the important work that they were doing there so near Chicago. There are a number present tonight, I think, who have been through the laboratory and have some ideas about it. There are some who come in contact with the work of the laboratory.

The paper of the evening is now open for discussion. First, I will call on Mr. North, who, I think, is acquainted with the work of the laboratory.

A. T. North, ASSOC. M. AM SOC. C. E.: During the past two years I have had occasion to visit the Forest Products Laboratory possibly ten times. It is with pleasant anticipation that I always go there and leave regretting the shortness of my visit. It is a place of great interest to anyone whose work has any relation to the use of wood in any form and it should be of great interest to any person interested in scientific research. The director, Mr. Weiss, and the large corps of scientists and engineers there employed, are always ready to give information that may be desired and to lend assistance in solving any problems germane to their work.

I think it a practical and feasible scheme for this laboratory to take up the question of the working unit stresses of our native structural woods. Mr. Weiss states that in our municipal building regulations there is sometimes a variation of one-hundred per cent in the allowable working stresses for the same specie of wood. This is undoubtedly true and at once impresses us with the fact that there must be an enormous waste of material where the working stresses demanded are too low. In my work I have had to do with the preparation of some building regulations for a few cities and know that a statement from the Forest Service always carries great weight with those who formulate the laws.

I would impress on you the necessity of basing the working stress for any wood on a definite grade of material or having various working stresses corresponding with various grades of the same material. As wood is a natural product it lacks uniformity and is defective to some degree and for this reason grades are required. Man-made material, like steel, is also made in grades, as soft, medium and hard, as desired for different uses. Various associations of lumber producers have established grades for their products but unfortunately they have graded for defects and not for strength only. Grading for defects is justifiable in finishing lumber where the appearance is the desideratum, although personally I have always thought that "strictly clear" finish voided many knots with the accompanying beautiful grain effects. It is granted that grading for defects does, in a way, determine the strength of a timber, but only in so far as the defects are concerned, and it is also true that grading for strength quality is the primary basis for all grading of structural timbers. This question with reference to yellow pine was discussed before this Society on May 11th of this year.

It is yet a matter of doubt if the producers of timber can ever secure the uniform adoption of a scientific grading rule, and it is needless to here explain my reasons for this opinion. It is therefore to be hoped that the Forest Service will at an early date cover these two important points and work for their adoption by all of our municipalities. Engineers and architects generally should lend all assistance possible to attain this end.

The work at Madison has the advantage that the tests are made on all woods on a uniform basis or program. Individual investigators following their own ideas present different results for the same tests on the same materials, and then the task presents itself of reducing the results to a uniform basis.

The laboratory is usable. Sometime ago I wished to secure data concerning the heat units given off by the combustion of a given volume of wood and the amount of air required for the combustion of a given volume of wood. I was unable to get these data in the Chicago libraries, but a request made on the laboratory brought a quick and complete response. The laboratory could aid engineers in the solution of many problems and especially in the matter of preserving wood for structural purposes and street paving.

I must confess that Mr. Weiss has mentioned work in many fields that I had never heard of even in my visits to the laboratory, and I think his address impresses us all with the magnitude and usefulness of this department of the Forest Service.

Mr. Grant: It would seem as though the work of this laboratory must touch upon the line of work of almost every engineer, no matter what he is doing. It certainly touches on our railroads and I will ask Mr. Armstrong if he has anything to add to the discussion.

W. C. Armstrong, M. W. S. E.: I do not know that I have anything in particular to offer. I would like to ask a few questions, which perhaps Mr. Weiss can answer.

Speaking of the creosoting process as used in piling and structural timber that is submerged in water, I would like to ask if any experiments have been made to determine the durability under such conditions as compared with the durability in a dry location. The question is suggested by the desire to use treated piles in a great many cases where they stand in water all the time—fresh water.

Mr. Weiss: I do not know of any tests that are being made to determine the relative durability in that condition. We do know, however, that if piling is kept constantly under water it will never rot.

Mr. Armstrong: The trouble with piling under such circumstances is that it will decay at the water line, the place where it is submerged part of the time and exposed to the air part of the time.

Mr. Weiss: I should think you would have there conditions which are quite comparable to driving a pole in very moist soil. Moisture is favorable to the growth of fungus and decomposition will be very rapid. Piling standing in fresh water where the air is moist around the pile, particularly if the location is shaded, is bound to deteriorate very rapidly and we have always recommended that in cases of that kind the engineer use either a very durable variety of wood, which does not need a preservative treatment (at least where preservative treatment is not so essential) or give that pile some kind of a treatment. If you cannot afford an expensive pressure treatment with creosote, use the brush treatment. A brush treatment would be quite effective.

Mr. Armstrong: That method of treatment would probably not be of much service in the cases I mentioned, of piling driven in water.

Mr. Weiss: No, it would not.

Mr. Armstrong: Is there any tendency for the creosote oil to leach out in the water?

Mr. Weiss: There is only a slight tendency. The volatile oils tend to leach out. The heavier oil is practically insoluble. We have analyzed piling which has been in place twenty-eight years and found the heavy oils remaining practically unchanged.

Albert B. Cone (with American Lumberman): I have for many years handled the bulletins of the Forest Service and those of the Forest Products Laboratory, in an editorial way, but it was only within the last two weeks that I had an opportunity to spend a day in inspecting the laboratory as thoroughly as that short space of time would permit. I think one might visit the laboratory as many times as Mr. North has done, and yet not know a very great deal about what is being accomplished there. In fact, I find that even individuals connected with the laboratory are not altogether well informed as to what each is doing. Each specializes in his own work and thinks if he keeps in touch with that he is doing very well. I went through all the departments of the work except one, which Mr. Weiss has not touched on in his pictures. The young man who was showing me about opened a trap door and I looked down into a cave of darkness. He said that was the fungus pit. They had all kinds of fungi from the woods in there, and were feeding the varieties in order to get a line on their performance.

I was at Madison with another member of the editorial staff, particularly with reference to this work they are doing as regards inflammability of wood. This zinc-borate process which they have investigated appears to be the best thing which has yet been developed. Various commercial products have been offered but they do not seem to stand the test very well when one gets thoroughly into an investigation of them. The borate process has certain drawbacks in that the weight adds to the shingle, which would rather require treatment at this end of the line than out on the Pacific Coast where they are tempted to overdry the shingle in order to reduce the weight. Personally I have been hoping that the process of rendering wood, shingles in particular, fireproof would follow out somewhat the chemical action which occurs when mercury bichloride is put into the wood, *i. e.*, combining with the albumen which is in the wood to form an insoluble compound—the kyanizing process, which is quite largely used abroad but very little in this country. If some albuminate should be found having a fireproof quality it would be, to my mind, a solution of the problem. Whether there is such an albuminate is, of course, a question. Some of the processes which are used in the waterproofing of paper might offer some hints in that direction.

I have always been interested in this question. No one appears to know exactly what the necessity is for the fireproofing of wood. We hear a great deal about inflammable frame structures and shingle roofs, coming from people who have the information, from insurance companies or fire marshals of cities; but from a very exhaustive search of the municipal fire records of this country I cannot find that any of the city fire authorities have compiled that information in an understandable form. Last Saturday I finished taking off the record for dwellings in the city of Chicago for the year 1913 separated as between frame and other constructions, and while the compilation is not yet complete, I found that in frame dwellings in Chicago the number of fires was smaller in proportion than in the number of brick, stucco and concrete dwellings, in so far as it was known how many there are of those buildings. That is something, also, that the city statistician should give us. The fire laddies are supposed to inspect all buildings at certain intervals but they do not make a census of them. While the city of Milwaukee can tell you how many buildings of each kind there are at any given period, the city of Chicago cannot. The City Manual says there are about 300,000 buildings in Chicago, of which about 169,000 are of frame construction and about 131,000 are of brick and other construction. When we come to analyze those figures, we will see that in other classes of construction than dwellings the frame construction must be in the large minority. Stores, factories and commercial buildings in general are not of frame construction. This will mean that as to dwellings there must be an excess of more than 100 per cent frame construction and the excess in fires is nothing like that,—approximately 26 per cent. I found that the average fire in a brick dwelling for 1913 was about $99.00, as I remember. In frame buildings the average fire was $114.00. So that the actual figures of inflammability do not carry out the great emphasis which is being placed upon the inflammability of frame construction. And that is rather to be inferred from the fact that the insurance interests and fire marshals who are making this agitation have never supported their arguments with any of these figures which are in their possession. They will tell you about any of the conflagrations in which frame buildings have cut a large figure, entirely disregarding the destruction of solid brick and stone and steel in Baltimore and San Francisco. A conflagration can occur. The question is, what does happen in the average fire experience of the country? That is something on which I have been trying to get some kind of a line. It seems to me if we get into those questions we ought to make use of the actual information which we have, and when we get that we will know the source of the disease from which we are suffering and be able to apply the remedy.

F. E. Davidson, M. W. S. E.: I want to ask the speaker if the laboratory has made any series of observations of the prevalence of dry rot in structural timbers? In other words, is the prevalence of dry rot of sufficient importance to demand a serious investigation as to the advisability of treating structural timbers? Again, has the laboratory made any experiments as to how to treat timbers?

Mr. Weiss: We have an investigator in the field who is now studying the problem of dry rot. He has gone through various lumber yards and found out just what precautions, if any, are being taken in order to keep those yards sanitary. Some of his photographs indicate that very few precautions are being taken. We have a great many photographs showing piles of decayed lumber right up against piles of perfectly sound lumber, and one can actually see with the naked eye the fungus going into the sound wood.

This investigator has taken up that end of it and that part of it has been completed. He has just finished the New England territory. He has gone through a good many silk mills, cotton mills, and woolen mills and some of his photographs surprised me. In some of those mills the timbers are absolutely white with fungus. I had never before seen conditions like that in buildings. In fact, the only place I have ever seen conditions that were in any way comparable, was in a coal mine. So I believe this question of dry rot is a serious one, and I believe it is a question the lumbermen must meet if they are going to sell their product in competition with those other materials which have not this objection. The silk and cotton mills in New England are attempting to get around the trouble by dipping their lumber in a solution of mercuric chloride before they put it into the factory.

Mr. Davidson: Sometime ago I visited a prominent lumber yard here in Chicago and was astonished to find just the condition existing that the speaker has mentioned,—piles of rotten lumber alongside of piles of new stock. I consider such practice on the part of the lumber dealers almost criminal.

I want to ask the speaker if the observation made on the prevalence of dry rot indicates that it is more apt to occur in buildings where there is a relatively high degree of humidity due to manufacturing processes? My own observation is that I have never seen a case of dry rot in a building where there is a very low degree of humidity. One case I want to refer to particularly. A few years ago I designed a heavy mill construction timber building in Pittsburgh. The floor construction was of the well-known laminated type, of 3-in. by 8-in. Southern pine dressed one side and edge. On top of the rough floor we laid one layer of waterproof building paper, and then put on the finished maple flooring. The office manager of the firm, after he moved into the building, was not satisfied with the appearance of his office, which was whitewashed, and had a contract executed for refinishing, paying for it, presumably, out of his office appropriation, as the contract did not come back to the main office for O. K. He had the ceiling of the office covered with a layer of waterproof felt and then covered it with a kiln-dried white oak ceiling. About three months after the building was occupied I got a hurry-up call to go to Pittsburgh, the report being that the building was coming down. I found the floor construction over the office had rotted. We took down all the fancy oak ceiling as well as the felt, patched up the floor, covered the rough floor on the underneath with burlap, calcimined it, and told the office manager to let the building alone. There has been no further trouble.

Mr. North: I have never found any dry rot, myself, except where the humidity was high and constant.

Mr. Weiss: As I stated a little while ago, we have not completed these investigations, but as far as we have gone we have found the dry rot is more prevalent under conditions of moisture such as exist in textile mills, where the air is warm and moist, and in basements, cellars and warehouses, where the air is stagnant. A peculiar thing about this dry rot fungus is the fact that it will develop in one portion of the building, say in the basement, and then send out its mycelia or threads a distance of fifteen, thirty, forty feet, or more, over stone or steel to reach sound wood. It has the power to manufacture for itself sufficient moisture to carry it over such spans. The only way to stamp out the trouble is either to give the timber a preservative treatment, or, in the case of a warehouse or cellar, increase the ventilation so that there will be sufficient fresh dry air.

Lyman E. Cooley, M. W. S. E.: I have been much interested in the researches at Madison, but I do not think that I can add anything that will entertain or enlighten. I was brought up in the woods—not exactly the backwoods—and I was profoundly impressed with the enormous waste in branches and those parts of the trees which are left in the woods and in the bark. Beyond certain points which have been brought out, I do not know what progress is being made in conserving that element of wood growth. It has been touched upon—certain features of it.

I was brought up in a sap-bush where they made maple sugar and I would like to know what effect the tapping has on the life of the maple tree; also, what is the effect of tapping trees for turpentine? I have seen maple trees tapped for at least twenty years and still yield a good supply of sap for maple sugar.

I am more interested, however, on the side of general conservation, as in the replacing of the timber on the waste lands. Is it not feasible to re-forest these waste lands that are not suited for agricultural purposes with trees which would yield an annual product like maple sugar and nuts and also furnish browse to members of the deer and caribou family, thus increasing our meat products? Of course, that is not the subject of this evening. I only raise the question for the purpose of calling attention to another angle of the forest question.

I would like to have the author give us his opinion as to the effect of tapping, on the longevity of maple and pine trees.

Mr. Weiss: Well, my answer would apply to both species. If you do not tap to excess you will not seriously injure the vitality of the trees. In tapping a maple tree for sap to make maple syrup, you are not going to weaken the life of that tree to any appreciable extent if you do not make too many holes in the tree and do not drain too frequently. The same is true in tapping a pine tree for turpentine. The French tap the same tree for thirty or forty years. The only danger in tapping either a pine tree or a maple tree rests in permitting decay to get into the wound. If, for example, one of the spores I told you about, alights on a wounded portion and succeeds in getting a foothold, it is liable to cause rot in the tree, whether in the pine or the maple. The rot will gradually extend through the tree and eventually kill it. That is the chief danger. If you can keep out infection and do not tap too severely you can keep up the tapping process almost indefinitely.

John F. Hayford, M. W. S. E.: When Mr. Grant made the remark that he saw at Madison this Forest Products Laboratory only a little way from Chicago and found it was new to him, that reminded me of a statement which I read today, a statement backed by a man who knows. I am sorry I was not quick-witted enough to bring the document with me, but the statement was of this kind: The aggregate of high-grade research done during the past decade by Government bureaus in the United States compares favorably with the aggregate of such research done in the same decade by all other institutions in the United States. That is the claim, that at least one-half of all the research done in the last decade in the United States—high-grade research—has been done by Government bureaus. I would like to say also that this statement was not made by a man connected with any Government bureau. The man who made that statement is the head of the Carnegie Institution for Research, an outside organization.

The point which I want to emphasize and bring home to you, if I can, is that there has been a tremendous growth in the last twenty or thirty years in research work done by the various Government bureaus. This Forest Products Laboratory of Wisconsin is one of those cases. I think I am safe in saying it is a bureau of research, a bureau grown up very recently. It is doing a large amount of research in an astonishingly able and efficient way, and yet it does not make noise enough to be heard against the din of Chicago.

Before I sit down I want to express my admiration not only for the work done by this laboratory but also for the remarkably able way in which the work has been presented before us tonight.

Mr. Grant: I want to reverse the order for just a moment and let the speaker of the evening propound some questions to the audience. I think he has one or two questions to ask.

Mr. Weiss: Turn about is fair play.

The chief thing I have in mind is this: I have been asked by the International Engineering Congress to prepare a paper on the preservative treatment of timber, to be delivered at San Francisco next July, I think. There will be but two papers, one from the United States and one from Europe. For this paper the instructions laid down are very strict. They want facts, not theories. They want to know what the engineering profession thinks about the preservative treatment of timber. I have written to a number of operators with whom I am personally acquainted and have already secured considerable data showing the efficiency of treated timber in service. But what I would like to get now is an expression of opinion as to the engineering worth of preserving timber. Does it pay? Is it worth while? Can you refer me to any specific cases where you have used treated timber, and the results secured? The paper is for engineers and I want to present it with perfect frankness. I want to show up the bad points as well as the good ones, and if any of you have had personal contact with treated timber I would be very glad, indeed, to hear of your experience.

Mr. Davidson: I recall one instance, in connection with the use of nailing-strips underneath wood floors, in factory construction. The construction is simply an earth fill, upon which the strips are laid and filled in between the sections to keep the rats out. Then a waterproof felt is laid, followed with the wood floor itself. I have found that the average Southern pine which we can secure in Chicago will last about five years before it rots out, and that creosoting these nailing-strips just about doubles their life.

Mr. Weiss: Is that because the record does not extend beyond that or is it the absolute limit?

Mr. Davidson: The record does not extend beyond that. I have also some experiments under way where the nailing-strips were treated with zinc-borate. That test has not been under way long enough to give definite results, but so far everything looks favorable.

W. C. Bauer: I should like to give an experience regarding electric light poles, which we usually consider to have a life of ten to twelve years. Ten years ago I put up a number of electric light poles in connection with a plant I erected, and used simply the brush treatment for a distance of two feet above the ground and three feet below the ground. The soil was yellow clay and, in some cases, blue clay, with practically no sand in it. I have a letter from a friend of mine who was aiding me at that time, who states that those poles are practically as good now as they were the day they were placed. He said, further, that the brush treatment certainly prolongs the life of telegraph and telephone poles.

Mr. Weiss: What kind of poles did you use, and when were they set?

Mr. Bauer: I think they were Michigan white cedar poles, and we used carbolineum. They were set in place in 1905.

Mr. Armstrong: I think Mr. Weiss might get some valuable information from the different railroad companies. Nearly all of the large railroad companies now have treating plants of their own where they are treating ties principally, and in many cases, piling and other bridge timbers. I am not in position to give any definite information without looking up the statistics, but the Chicago & Northwestern Railway Company has a treating plant and has been treating ties and timbers for a number of years. They have not made any accurate experiments on increased life of ties but are arranging now to make such experiments by marking ties in the track and noting the effect from year to year for different kinds of treatment. There are a number of roads, I think the Santa Fe, for instance, which have used timbers very largely in timber trusses—what they call ballasted floor timber trusses—where the timber is covered with ballast. I could not say what their experience has been, but I am sure that they would be very willing to furnish Mr. Weiss the result of their experience, which will be of value in preparing the paper referred to.

Mr. Cone: I would ask Mr. Weiss if he thinks it is possible to obtain timber so free from the spores of dry rot that when placed in a condition as favorable to incubation as those textile mills, it will remain sound. In other words, does the previous infection cut any figure?

Mr. Weiss: It is almost impossible to get a piece of timber that has not some evidence of decay and if placed in a favorable position that decay is likely to develop. We are attempting to kill two birds with one stone in some researches that we started last week. You know that pine lumber when cut and piled in yards gets sap stained, which is considered a defect in certain grades. The ordinary method of overcoming that is to dip the lumber in a solution of bicarbonate of soda, about six per cent. We found in our laboratory that dipping that lumber in a solution of sodium fluoride is more effective than sodium bicarbonate. Furthermore, the sodium fluoride is toxic to fungus so that at the same time we are keeping sap stain out we hope to keep out, also, infection. These experiments are under way now. It may develop in being worth while commercially to give these timbers a dipping in this kind of antiseptic in order to keep them more or less sound at the time they are placed in buildings.

SOME ASPECTS OF THE WORK OF THE ILLINOIS UTILITIES COMMISSION

ROBERT M. FEUSTEL

Presented October 19, 1914

When your Secretary extended the courtesy of my meeting with your Society to address you on the work of the Illinois Commission, a number of subjects suggested themselves to my mind. A paper dealing with any of the varied problems of an engineering and economic nature which present themselves to the student of public utility matters, would have required considerable more time than was at my disposal. Such a paper would also more properly come after the Commission had considered these problems for a greater length of time and prepared orders in which the same were involved. It occurred to me that a brief talk on the every-day problems which have confronted the engineers of a Utilities Commission would be of some interest to your Society.

Let us consider first, briefly, the reasons for the existence of a Utilities Commission. On the part of many engaged in the engineering business, and particularly those engaged in the utilities business, there is a fairly well-defined impression that the regulation of public utilities is merely a result of a popular and rather temporary feeling that large corporations of all kinds are a menace to the public and should be hampered as much as possible in the conduct of their business. This feeling is shared very generally at the present time by those who are responsible for the conduct of practically all classes of business, and many of the utilities feel that they have been rather unjustly singled out for the maximum amount of such interference by the public. The facts would be perhaps better stated if it were said that this had been the feeling of the utility companies some two years ago. The writer recalls quite distinctly, in his connection with one of the earliest Utilities Commissions, some seven years ago, the attitude which was taken by the companies when investigations of their properties were in progress. Requests for information which were within the legal right of the regulating body to make, were met on every hand by delays on the part of the companies. The idea that the public should have any part or any interest in the manner in which public utility businesses were conducted was inconceivable to the operators. Every available legal obstacle which could be raised was put in the way of the investigator of the regulating body. It is not at all unnatural that such should have been the case, as the idea was distinctly a new one, and it is a normal human tendency to desire that the conduct of a business in which one has invested his money and is daily investing his time and interests, should not be interfered with by outside parties. Municipal ownership or municipal control had, in many cases, played havoc with what had once been flourishing utility properties, and the operators were fearful that regulation by a Commission empowered with great authority might readily lead to the worst form of paternalism. The public, on its part, proceeded rather calmly with the idea that it did have authority to deal with these properties in matters of rates and service, and the creation of new commissions became an annual occurrence. It is not the intention of the writer to enter into a lengthy discussion as to the legal rights of any community to regulate public utilities, but merely to point out what the writer believes to be the equity of the case in the stand that was taken by the public. The utility companies were, for the most part, operating under franchises granted by the public and made necessary because of the use of public thoroughfares by the utilities in the conduct of their business. Certain clauses in these franchises, and the existence of the franchises themselves, formed the technical legal background for most of the claims that the public did have authority to regulate utilities in the matter of rates and service. It is believed, however, that there were other far more important factors which entered into the case.

The service rendered by the utility companies, for the most part, was formerly rendered in one form or another by the individual himself, or at least by some common interest to a comparatively small group of individuals. With the aid of modern invention it was soon recognized that this service could be rendered more economically and efficiently to the entire community by some larger organization. In the beginning several such organizations came into existence in most every community. Combinations were made, however, and it soon became the general rule that only one utility was rendering service of one kind in any community. It was recognized that this was the wise and economic thing to do, as duplication of plant properties, while it often effected a temporary relief to certain consumers during the time that a rate war was in progress, in most cases resulted in a final wiping out of one of the companies, or a lowering of the grade of service furnished by both of them. The monopolistic feature of utility operation at once came into existence as a desirable working arrangement for the consumer. Unfortunately, the management of a great many of the utility companies did not measure up to the vote of confidence which was virtually placed in them by the public. Service complaints improperly handled and high rates gave rise to much dissatisfaction, and the new problem was met in various ways, depending upon the character of the community. The objections, for the most part, it is believed, were in the nature of service complaints rather than of rates, and it is really the service feature which is now of greatest importance to the consumer.

There were two possible solutions of the problem—public regulation or public ownership. Public ownership involved various burdens, which many communities were unwilling to assume; and public regulation was the next and most natural step.

It is the writer's belief, therefore, that the equity of public regulation of utilities is about as follows:

1st. A realization that the life of a community depends largely on the service which is now rendered by public utility corporations.

2nd. This service can, for the most part, be rendered more economically by an organization having a virtual monopoly in any one community.

3rd. It was found impractical to expect that the highest efficiency would be rendered by any organization having a monopoly in a community without regulation.

4th. The natural desire of a community to obtain the economies of private management under proper regulation before assuming the burdens of public ownership.

The law creating the State Public Utilities Commission of Illinois, known as the "Utilities Act," is similar to those in force in various other states throughout this country. As drafted, most of these laws seem to attach the greatest importance to the matter of rates, but all of them deal quite generally with the service that is to be rendered. As above stated, the writer believes that the laws should read "Service and Rates," as probably three-fourths of the amount of work handled by most Utilities Commissions is along the lines of service investigations.

The Illinois Utilities Act classifies all common carriers and all companies furnishing heat, light, power or cold, or engaged in the transmission of messages in any form as utilities, and brings such companies within the jurisdiction of the State Public Utilities Commission. It makes it mandatory upon the Commission to establish standards of service for the utilities, and to make investigation and issue an order in all cases where a utility desires to raise a rate, either directly or by change in classification, for any service being rendered. It also makes it incumbent upon the Commission to investigate and render a decision in matters of any rate which is believed to be unreasonable, or any service which is considered unsatisfactory, upon formal complaint of any consumer. I would like to say here that in this respect the Illinois law is probably more liberal than any other law in the country. In fact, as the law is written, in Illinois if an individual consumer desired to make a formal complaint on a rate and to follow it up, unless the Commission could show pretty thoroughly that there were grounds for not investigating the complaint, this one consumer would be in a position to throw the company and the Commission into a full-rate investigation. In Wisconsin it takes twenty-five consumers. In most states it takes a certain number of consumers. In short, the Commission has regulative powers in practically all matters regarding service and rates. Of course, the usual recourse is afforded either the consumer or the utility to appeal to the courts, in case a finding of the Commission is considered at variance with the merits of a case.

Special provisions in the Act itself, and regulations later adopted by the Commission, make it necessary for the utilities to prepare certain regular operating and financial reports, to be placed on file in the offices of the Commission for use during special investigations. That is, the regular financial reports are asked for so that comparative statistics may be had at such time as a rate investigation must be made. Certain petitions must be filed, such as permits to construct wire crossings over railroads, railroad crossings over highways, transmission lines or railroads into new territory; and orders must be issued, granting or denying such petitions. All of the latter regulations are for the purpose of effecting a uniformity of practice and to aid in adequate supervision as regards human safety and satisfactory service, as contemplated by the Act.

In order to carry out these many duties it became necessary for the Commission to create various departments, and employ competent men to make investigations and collect data on which to base their decisions. The Legal, the Statistical and Accounting and the Engineering Departments have thus far been created by the Illinois Commission.

The problems which are assigned to the Engineering Department may be first classified into two main groups—formal and informal. Informal cases are those in which no hearings are held. but the investigator gathers the facts, and, as an impartial arbitrator, attempts to make an adjustment of a case, either by correspondence or by a conference between the interested parties. Probably sixty per cent of the work carried on by the Commission is in response to informal complaints. To my mind the ideal condition would exist if ninety per cent of the work of the Commission were handled informally. In this way the Commission could act in the nature of a central clearing house between the utility and the consumer. But the utility may say, "What is the need of having these informal complaints brought to the attention of the Commission, as complaint departments are maintained by the companies?" It is true most utilities have such departments, but the measure of their real service to the consumer is the amount of unrest to be found in most communities regarding utility service. In certain communities there appears to be an almost perfect confidence between the consumer and the utility, and from such places the complaints are almost negligible. In other districts the differences which arise are almost continuous. It is impossible to state the exact cause of such condition, as there are special contributory factors in each case. The character of a community and the extent to which utility problems are made political issues, have considerable bearing. However, the character of service being rendered, in the full meaning of the term "service," which includes regularity, uniformity, promptness and courtesy in all departments, is usually the deciding element as to whether or not a utility is in good favor with its patrons. The results of the informal complaints do not, as a rule, appear in the published reports of the Commission, but they are in the same way the measure of much of the real service that is being rendered by a Commission.

The formal cases are those in which hearings are held and evidence is presented by either one or both sides to a controversy. In certain cases such hearings and more complete investigations are, of course, necessary. Especially is this true in making a determination of what should be a reasonable rate for any service rendered. The utility quite often is not fully aware of what the actual cost of the service is, in a particular case, and data must be collected and proper apportionments made.

In a formal rate case, the utility is notified by the Commission that an inventory and appraisal of the property used in serving the public must be filed with the Commission within a specified reasonable date. This is rather a departure in the case of the Illinois Commission from the usual practice. In Illinois we were confronted by the fact that we had probably the greatest value in the matter of railroads and the second largest value in the matter of utility properties of any state in the Union. The Commission had a limited appropriation and certain valuation data were necessary for all rate cases. We cast about for some method to keep down the expense and still secure the necessary data for each rate case, and it was this dilemma which caused the Commission to ask that valuations be prepared by the companies. The Illinois Commission has taken the position that, in all rate cases, these appraisals shall be requested from the utilities. A bulletin is being prepared at this time, setting forth the classification of inventory which will be required in the filing of valuations for the various kinds of utility properties. This bulletin will also ask for the detail of unit prices and will specify what factors shall be included in unit prices, overhead, etc. I do not mean by this that it will specify anything as to how much shall be included for any particular items, but we will want the companies to list out what they include; for instance, whether they are including contractor's profit in their unit cost and things of that nature. In this way it will be possible to have a uniform practice, and much of the time which is now consumed at hearings in adjusting differences due to a difference in classification in the valuations prepared by several witnesses, will be saved. In testimony before courts and commissions on the item of overhead charges, expert witnesses have in recent years come into considerable dispute because of the wide range of evidence offered by reputable engineers on the same case. Much of the apparent difference of opinion has been due to the variation in inclusion of items which go to make up this charge. Engineers should be able to agree almost exactly on quantities, and unit prices are also subject to rather definite analysis. If it is possible, therefore, to have a more uniform practice in preparing and presenting valuations, much of the cumbersome and expensive cross-examination which is now a part of most rate cases, can be avoided.

After the company has filed the appraisal the same is checked to unit prices. If the community employs experts to make a separate appraisal, it is the purpose of the Commission to request that such valuation also be presented in the form prescribed by the Commission. The valuation which will finally be presented to the Commission by its Engineering Department is made up after a careful investigation of the physical property and an examination of all appraisals submitted. The Commission then affords both the city and the company opportunity to cross-examine and enter testimony in regard to any differences which may appear in the final fair value as found by the Commission's engineers.

The Engineering Department, which has been organized to make the needed investigations, is as follows:

Chief Engineer.
Assistant Chief Engineer.
Consulting Engineer—Railroad Department.
Gas Engineer.
Electrical Engineer.
Telephone Engineer.
Mechanical Engineer.
Chief of Service Department.
Assistant Engineers.
Safety Appliance Inspectors.
Clerks and Stenographers.

In deciding to ask the utilities to present the valuations, the Commission has made possible an organization which, the writer believes, will work an advantage both to the public and to the companies.

It costs usually only about ten to fifteen per cent as much to check a well-made appraisal as it does to make the original valuation. In most cases the company would desire to make its own valuation, even though the Commission made an independent appraisal. It would mean two sets of investigators going through the same detail and interfering with the operators more or less as must be the case. The checking of the appraisal can be done with accuracy without much of this trouble and expense. Inasmuch as it is now unnecessary for the Commission to retain the very large staff which would be necessary in a state of this size, if independent valuations were made in every case, it is now able to employ competent experienced men as heads of departments to direct the checking and to work out the main problems. For instance, some of the commissions have employed what might be called the understudy method, in which they would have a head of the department and would have assistants in that department who would practically confine their efforts to the one department. There is a great deal of merit in that kind of system and it is probably more necessary where the commission is going to make the original valuations. The assistant engineers who are not permanently assigned to any particular department, are ment. In this way the staff can be employed at what might be called the most desirable load factor and, we believe, at a saving to the State.

As stated above, the Utilities Act makes it mandatory with the Commission to fix standards of service for utility companies. Up to the present time standards have been adopted for only the gas and electric utilities. The engineering staff made a study of all the rules and regulations, fixing such standards which had been adopted by the different cities and commissions throughout this country. The regulations, as suggested by the United States Bureau of Standards, were also considered. A careful study was made of Illinois conditions and a tentative set of rules were drafted, copies of which were sent to the utilities. A general hearing was held at Springfield in July, to which all the utilities were invited, to discuss the suggested rules. Notice of the meeting was also sent to a number of the large cities in the state, in order that the city authorities interested might be present and enter the discussion. Each rule was read and discussed thoroughly, and a record of the discussion was made by a court reporter. At the close of the meeting an additional two weeks were given all interested parties in which to file any further comments or suggestions. Much profitable information was obtained, particularly regarding special conditions existing in Illinois. The rules were then carefully reconsidered and all the suggestions which seemed fair and reasonable were incorporated in a final draft, which was passed by the Commission the latter part of September, to become effective November 1st, 1914.

The rules adopted cover in the main the same points which are considered by other commissions, but special provisions are made to meet the Illinois conditions. In no other state in the Union is found such varied practice by gas and electric companies. We have at once the largest water power development in this country furnishing electric energy in Illinois, the largest individual gas company in the world, in the matter of output and value of physical property, the greatest development in this country in high pressure transmission of gas, the greatest development in this country in the tying in of many small communities by electric transmission lines being served from central power stations, and at the other end of the scale individual coal or water gas plants in cities of less than five thousand, and lighting plants with less than one hundred and fifty consumers. With such a wide range of conditions it is apparent that any rule fixing standards for gas and electric service should be made rather flexible in character. Ample provision is made giving any community or utility the right to ask for a revision of any of the rules to meet special local conditions, and it would, of course, be unusual if some such requests were not made in the near future. Rules establishing standards for steam heating, water and telephone service, are now being prepared, and the same course will be adopted standards.

The best standards possible would be of little use, however, if there were no method of following up such rules to see if the utilities conformed in their practice to the same. For this work the Service Department of the engineering staff was organized, which at present consists of a chief and four inspectors. The State is divided into districts, and all service complaints are sent to the man in charge of the particular district in which the complaint originates. I might state that the headquarters for the four districts at the present time are Chicago, Peoria, Springfield, and East St. Louis. This is just a start on our service work. There is no doubt in my mind, with the great number of utilities we have in Illinois, that it will take eight to ten inspectors to cover a district adequately for the routine inspections which are really necessary. If an adjustment can be made on the ground, it is so done, and results reported to the Springfield headquarters. If no settlement can be made, the facts are reported to the Chief of the department, and further attention is given, either by correspondence or by a visit on the part of the head of the Service Department. If no final adjustment is effected, the case is set for formal hearing in the usual way.

In addition to handling the informal complaints, the district inspectors make routine inspections of the service being furnished by the plants in their districts. These inspections are made without the knowledge of the utility that tests are in progress. The reports are sent to the main office and the utility is notified in what way the service is unsatisfactory, and later a follow-up test is made.

In the case of the small privately-owned plants the inspector is often able to give valuable suggestions for improvement in service and the results of the best practice in any of the districts is made available to any plant operator through the regular conferences of the inspectors.

A personal call on a consumer who has a complaint and a joint call on the utility operator usually results in a settlement of the complaint. The consumer comes with the inspector, who is not an advocate, but a disinterested arbitrator. In most cases it results in an explanation of the reason why certain rules and regulations are necessary, and a better understanding is had between both parties. And this is the real business of a Utilities Commission,—promoting a better understanding between the utility and the consumer.

I feel that it is impossible to refer too strongly to the importance of the service feature of our work. Sometime ago in making a street railway service study of the Winnipeg street railway lines, the writer had occasion to study the service being rendered by most of the larger electric railway systems in this country. Investigation was made of the public sentiment as regards various company practices. There was one property which seemed to stand out head and shoulders above all the rest in the matter of being in public tion of about half a million, was on a straight five-cent cash fare basis. Within three hundred miles was a system in a community not more than half the size, where tickets were sold six for a quarter at all times, and eight for a quarter during limited hours and on Sundays. There had been no agitation for reduced fares on the first system, however, because the company was one which realized the true meaning of the term "service," and the patron felt that he was getting the real value of his money. The rate, therefore, is not the real objective at all times to the consumer, as is often supposed, but he will demand that the service rendered be commensurate with the rate.

An investigation of the cost of furnishing any particular class of service usually demands the greatest amount of detail work. Such cases are subject to more or less definite analysis. But even when the answer is obtained upon a theoretically correct cost basis, it is not always the one which can be used. In a water case, for instance, it can usually be proven that the actual cost of the service rendered to the small consumers who live on the outskirts of a city is greater than the charge which can be made for the service. It is of vital interest to the community, however, that, for sanitary reasons, as many as possible of the residents use water service. Those who are better able to pay, usually live closer to the center of distribution, where land is more valuable, and where the theoretical cost of water service may be less. They can often better afford to pay the extra cost of water service rather than submit themselves to the danger and eventually pay the price in the form of increased taxes to prevent the spread of contagious diseases, which may result from unsanitary conditions. This is really not a far-fetched illustration, and there are a great many more aspects of the problems which daily inject themselves into the work when human safety and general welfare are considered.

Regulation is, therefore, not a cut-and-dried form of computing exact costs of service and exact rules for operation. It is an attempt on the part of the people to better the general conditions under which they are living. It is one step in the great movement of solving the economic and social problems in a community. The public very generally realizes that certain practices which now seem obnoxious are the result of what appeared to be a perfectly normal development at the time. It further realizes that all such practices cannot be corrected at once without a serious wrench to institutions on which the community's welfare depends. But it is very generally to the future that it looks in order that the conditions may be gradually improved.

I believe this, then, is the work which the public desires that a regulating body should do: Investigate carefully the real relation between the public and the utility companies, bring about a better understanding as to the coördinate interests which exist, look first to the human safety, and then see that the best service commenests to be sure that the operators are paid fairly for the money and efforts invested in the business.

DISCUSSION.

W. D. Gerber, M. W. S. E. (Chairman): We have certainly been given an insight into the feelings of the Utilities Commission of this State as regards public utilities.

I would like to ask a question. In naming over the list of utilities which were included in the law, that of waterworks seems to have been omitted. Was that omission on your part or in the law?

Mr. Feustel: It was overlooked on my part.

Mr. Gerber: It is being considered as one of the important utilities of the State.

The meeting is now open for general discussion. Perhaps Professor Pence will favor us with some remarks.

W. D. Pence, ASSOC. W. S. E.: I had not expected to take part in the discussion, but I have been much interested in hearing this admirable presentation of the progress made in Illinois in the regulation of public utilities. It is probable that there will be found more or less distinct differences in the local conditions in the different states which may require some difference in the method of regulation. In a general way, however, the problems met in neighboring states will not be materially different, one from the other. There is one point of difference that I noted between the Illinois law and the public utilities laws of Wisconsin and of Indiana, and that is in reference to the control of the publicly-owned utilities. In Illinois I believe the regulation of municipally-owned utilities is not included under the law. I believe in only the two states mentioned,—Wisconsin and Indiana,—is the law made to include the regulation of the publicly-owned utilities. It has seemed to me that this is a desirable thing for the sake of securing a direct comparison between the quality of service and the various other things that enter into a comparison of that kind when it is desired to have the entire subject put upon its merits. The progress that has been made in these two states, at least in one of them where I chance to be somewhat familiar with the conditions, has been in the direction of making progress toward the final solution of this problem of public-service regulation by placing the publicly-owned utility on a common basis with the privately-owned utility.

Another subject which might be mentioned, which, I think, was not dwelt upon particularly in the paper, was the matter of the indeterminate permit. As I understand it, that is not included in the Illinois law.

Mr. Feustel: I would like to say something about the two points that Professor Pence has raised. (This is a purely personal opinion and in no way official.) I personally believe that the indeties law, certainly one which is as broad as the Illinois law in the matter of the control of the privately-owned plants. I mean that a law which gives a regulating body full control in matters of rates and service over privately-owned utilities, should protect these properties, when they are giving good service at a fair rate, from competition and from franchise troubles with the city. That, as I said, is purely a personal opinion and my work in Wisconsin helped strengthen this opinion. Our experience with the municipally-owned plants in Wsiconsin, particularly in respect to service, certainly would lead us to believe that the municipally-owned plants far more than the privately-owned plants were in need of service regulation.

Douglas A. Graham, M. W. S. E.: The subject covered by Mr. Feustel's paper is one of particular interest to many men in this Society. The Illinois Commission is just beginning its work and every time a new commission is organized we all watch its developments with interest and with the hope that it will shed further light on some of the many questions of equity and logic that are still the sources of dispute in valuation cases.

One of these questions with which we are all familiar is the matter of paving over street mains, and another is the estimation of "Going Value," and connected with this latter are several other overhead and so-called intangible values. It will be a matter of great interest, therefore, to see along what lines the new Illinois Commission will develop its policy and what attitude it will take on many of these disputed points.

There is one thing in Mr. Feustel's paper which, I think, deserves especial mention and I was glad to see that he did place considerable stress on it. I refer to the Commission's efforts to bring the utilities and the consumer together when difficulties arise. I think it has been the experience of most utility men that a large number of complaints that are made and difficulties which arise between the utility and the consumer are due to misunderstandings and lack of information on the part of the consumers, and to failure to understand the viewpoint of the consumer on the part of the utility companies. I do not think too much stress can be placed on the advisability of bringing the two parties together rather than going to all the trouble and expense of a formal hearing.

Mr. Feustel spoke of a new bulletin that the Commission is getting out, prescribing the rules under which inventories and valuations should be made. How soon will those rules be available to the public?

Mr. Feustel: That bulletin will probably not be available before ninety days. It will be in print in about sixty days. We have, however, blue-print copies of the tentative classification of the inventory which we have adopted, but no instructions. We have been issuing, rather, letter instructions in each case. Those blue-print copies, which represent nearly the final form as far as classification of inventories is concerned, are available at the present time.

before the Commission, can such instructions be obtained from the Commission?

Mr. Feustel: Yes, they can.

Mr. Graham: The Ohio Utilities Commission has ordered all of the utilities throughout the State to present valuations at once. Is it the intention of the Illinois Commission to make this general order or just to order inventories when it is necessary?

Mr. Feustel: Decidedly not. The Illinois Commission does not think that blanket orders for valuations from all the companies would result in anything but great expense to the companies, great trouble in filing the valuations on the part of the Commission, and practically a renewal of all the work any time a rate case might come up after two or three years. I do not know whether you meant in your suggestion as to paving over mains and going value and overhead charges, to put that in the form of a question. I hardly think you could be making such a suggestion. Of course, it would be impossible for me to state what position the Commission is going to take. A good many of those problems are now being considered in rate cases that are before the Commission.

I might say that the general tendency of most commissions and most courts has seemed to be that no value for paving over mains or conduits shall be allowed for rate-making purposes unless such paving is actually disturbed in the laying of such conduits or mains. That has, in general, been the main practice of the Wisconsin Commission. In the Appleton Waterworks case they were instructed somewhat vaguely by the Wisconsin Supreme Court that some consideration must be given paving over mains, but the court left the matter open upon that point and did not say how much or whether the total value should be allowed. Certainly my own personal view would be that I can hardly see the equity of allowing the total value for paving over mains for rate-making purposes. Of course, under the cost-of-reproduction plan, if we were following the strict theory we must include the total cost of paving over mains, but I believe the cost-of-reproduction theory has only been adopted in rate-making cases in the absence of data to show what the fair investment has been. The cost-of-reproduction theory, like any other theory, can be carried to a point of absurdity, and I believe allowance for all paving over mains, whether disturbed or not, is an absurdity.

Mr. Graham: It was not my intention to bring out a discussion on those points, because I imagine that the Commission has not yet formulated its policy on such matters. My thought was that the tendency of new commissions seems to have been to follow the rulings of the other commissions in the points mentioned; and, inasmuch as "Going Value" and "Paving" have been subjects of a great deal of controversy between men of reputation and well-known ability, it is my hope that the Illinois Commission will try along the lines of a broad interpretation of the issues, as determined by the logic and equity in the case, rather than founding its opinion purely on precedent. I realize that any detailed discussion on such a subject would last much longer than this Society would care to hear from either of us tonight.

Mr. Feustel: I would like to say, not as the engineer of the Illinois Commission but really as an outsider, as far as Illinois is concerned, I entered the work with some trepidation because I had known what had happened to some of the other Commissions as far as general policy was concerned, and I want to seriously voice my appreciation of the thoroughly fair and equitable way in which the Commissioners have been approaching the problems which have been put up to them. They have thrown aside technicalities in their cases and, as you have said, not merely followed precedents but their decisions have been based upon the merits of the individual cases. I certainly feel that they have been doing this thing to an extent that will make them a power for good in the State of Illinois.

Mr. Gerber: Mr. Finley, can you add anything to the discussion from the railroad standpoint?

W. H. Finley, M. W. S. E.: I was very much interested in what Mr. Feustel said regarding the Commission and its work. I look at the State Utilities Commission rather in a broad way. I believe the intention was to accomplish something good, but I think it is impossible to do it all at once. It is going to be a process of evolution and growth. I think that public utility bodies and corporations should join with them and lend their best efforts to the working out of these various problems, and, I believe, if they do it will result in lasting good not only to the community but to the corporations and public-utility bodies. Of course, we have a number of states in this Union and if the rules and orders of the different commissions are not coördinated it is going to result in more or less confusion. Take the case of a railroad, for instance, that runs through several states. Different states are passing different laws regarding different clearances. It will require some very good engineering to meet the wishes of all the different states in the matter of clearances. I think that such problems are going to be rather difficult ones for any commission to solve to the satisfaction of all parties concerned.

But speaking from my own personal experience with our State commission, I find that the personnel of these commissions is broad and liberal minded, and I have no doubt that we will reach a satisfactory conclusion in the end.

Mr. Feustel: I would like to correct one possible false impression I may have left in a remark I made in the first part of the paper. I spoke of the obstacles which had been put in the way of the investigating body in the past. I certainly want to

Commission, that the utility companies (under the Illinois law, railroads and all the other utilities are included) have certainly met the Commission far more than half way. They have responded to all the requests, and particularly with a new commission those requests must be numerous for statistics and data of all kinds, and we have had no difficulty whatever in receiving the heartiest coöperation from all the companies.

Peter Junkersfeld, M. W. S. E.: I do not know that I can add very much to the discussion this evening, but I wish to express my appreciation of the way in which Mr. Feustel has described to us the work of the Commission and particularly the rather broad statement he made as to the real function of the Commission, namely, to make for better understanding between utilities and consumers. His remark that sixty per cent of the work of the Commission, or at least of the engineering department, was in the way of informal adjustment, I think augurs very well. Anyone who has had experience in public-utility work knows that there are a great many little misunderstandings that arise solely from lack of information, and if the Commission would do nothing more it would justify its existence many, many times over.

Some of the leading people of the country in many of our utilities have for a good many years recognized that regulation by competent bodies is a very desirable thing, desirable for the stockholders of the various utilities as well as for the public,—and what we have heard this evening from Mr. Feustel as to the work that has been so well begun in this State I think fully bears out that opinion.

COON RAPIDS LOW HEAD HYDRO-ELECTRIC DEVELOPMENT ON THE MISSISSIPPI RIVER NEAR MINNEAPOLIS, MINNESOTA

J. W. Link, M. Am. Soc. C. E.*

Presented November 16, 1914.

In the sixty miles of the Mississippi River between St. Anthony Falls in Minneapolis and the dam at St. Cloud, Minnesota, there is a total fall of about 165 ft. or an average fall per mile of 2.75 ft. As the banks of the stream are comparatively high and steep, and as this reach of the river is so near the cities of Minneapolis and St. Paul, the site has attracted for a number of years considerable attention as being favorable for hydro-electric developments. With the exception, however, of securing various possible sites for development, practically nothing had been accomplished toward the construction of such plants prior to December, 1912.

In 1909 the Great Northern Development Company of Duluth, Minnesota, started to secure the necessary lands and rights for the development of a hydro-electric plant at Coon Rapids, which is located about six miles above the city limits of Minneapolis. After making necessary surveys, securing certain lands, and making a number of borings at the assumed dam site, this company secured the passage of a bill by the United States Congress under the general dam act of June 23, 1910, authorizing the construction of the dam, and this bill was approved January 12, 1911. The bill as passed required the work to be done under the approval of the U. S. War Department, and also required that the work be begun before January 12, 1912, and completed by January 12, 1914.

A preliminary set of plans was drawn up and submitted to the War Department, and received the approval of the Chief of Engineers September 20, 1911. After receiving the approval of the War Department practically no work was done, with the exception of building a small section of an earth embankment at the north end of the dam to comply with the requirement of the bill that work must be started before January 12, 1912.

Early in 1910 the Great Northern Development Company offered this property to H. M. Byllesby & Company, and the latter company, after making careful investigation of the situation, turned the proposition down as being commercially impracticable, when considered as an isolated plant, on account of the great variation in stream flow and the consequent necessity of having to maintain a steam reserve of nearly as large capacity as the water-power plant.

In the fall of 1912, after H. M. Byllesby & Company had secured the management and operation of the Minneapolis General again offered this property to H. M. Byllesby & Company; and the latter company, after considering the proposition on the basis of one unit in the Minneapolis system, decided that the project was commercially feasible and proceeded to acquire the property and to develop it.

---

*Hydraulic Engineer with H. M. Byllesby & Co.

The plans of the Great Northern Development Company as approved by the War Department contemplated a hollow or cellular dam. But after a careful canvass of the situation and study of the ice and logging conditions obtaining on the river, it was decided that a solid gravity section dam would be a safer structure and could be built as cheaply as the other. In accordance with this view of the case a modified set of preliminary drawings was made and submitted to the War Department. These modified plans were approved by the Chief of Engineers December 19, 1912.

As the permit for building the dam required that it should be completed by January 12, 1914, the time remaining in which to design and construct the work was less than thirteen months from the time the modified plans were approved by the War Department. It was, therefore, necessary to get all the speed possible, and to this end a survey party was immediately put in the field to check up the flowage and land lines, and make additional borings, test pits, etc.

A construction superintendent was appointed as promptly as circumstances permitted and he arrived on the ground December 17, 1912. As there were no houses near the site of the work, the superintendent's first efforts were necessarily directed to providing a shelter for himself and a small number of carpenters before work could be started on the camp for the construction force.

HYDROLOGY.

Precipitation observations have been made at St. Paul since 1859. These data show that the average annual precipitation from 1859-1911 was 28.6 in. and that the minimum annual precipitation previous to 1910 was 14.9 in. In 1910 the precipitation dropped to 10.2 in., with the result that the discharge of the Mississippi River at Minneapolis for the twelve months from June 1, 1910, to June 1, 1911, was the lowest of which there is any record.

Since the spring of 1912 there has been a gradual increase in the discharge of the Mississippi River at Minneapolis and at the same time there appears to be a marked change in the form of the hydrographs; the discharge appears to be more uniform and the flood peaks to be reduced in number and in intensity. This change in the stream flow, if real rather than apparent, is probably due, in large measure at least, to the storage reservoirs maintained by the U. S. Government on the upper watershed. There are five of these reservoirs, with a combined capacity of 90 billion cubic feet, or approximately 3,000 second feet for 365 days.

improving navigation below St. Paul, and it follows that the operation of these reservoirs must have a marked influence in reducing the spring floods and increasing the stream flow in the dryer seasons. On the other hand, as these reservoirs were natural lakes, the holding of the impounded water during the winter months may diminish to some extent the winter flow of the river.

At Coon Rapids the developed head will vary from 20 ft. at extreme low water to about 11 ft. at times of maximum floods, but as the larger floods are of short duration, the extreme low head will obtain for only short intervals of time in the years of highest river discharge, and not at all in years when the river is normal or below normal. As a result of this condition, the average head will probably be 17.5 ft. or more. The water surface in the reservoir is held practically at a constant elevation in order to get the maximum head possible at low water and to avoid damaging other properties at high water, and this constant reservoir level accounts for the great reduction of head during floods.

The U. S. Government and the St. Anthony Falls Water Power Company have kept records for a number of years, of the discharge of the Mississippi River at St. Paul and Minneapolis respectively. From a study of these hydrographs it was seen that a flood of 60,000 second feet might occur, and that floods of at least 15,000 second feet could be expected any time in the year, except possibly in the months of December, January, and February. It was also seen that the minimum quantity of water to be taken care of during construction might probably be as much as 4,000 second feet, although the minimum flow of the stream at this point sometimes drops as low as 1,500 second feet, but only for a day or two at a time.

On account of the liability of floods at any stage of the work it was necessary to design all cofferdams with this in view and to so plan the work that the least damage would result in case of the over-topping of the cofferdams. In order to be prepared for floods, arrangements were made with a party at Little Falls, 80 miles above the Coon Rapids site, to notify the construction superintendent by telephone as soon as any considerable rise in the river was noticed at that point. This information gave 24 hours warning of approaching floods and furnished sufficient time for getting the work in shape to prevent damage when the floods arrived.

The maximum discharge of the river during the progress of the work was approximately 12,000 second feet, and at this time the cofferdam was over-topped at a point where it had purposely been left low, but the flooding was quickly stopped by the use of sacks of sand, so that no damage resulted.

BORINGS.

The investigation for foundations made by the Great Northern Development Company consisted of a line of wash borings running borings were made at intervals of about 100 ft., and in addition to this a considerable number of scattered borings up and down the stream from the main line were also made. These borings developed the fact that the formation was glacial drift of such a depth that it was impracticable to carry the foundation down to bed-rock.

The samples obtained from these wash borings did not give much indication of the character of the materials as they lay in place beneath the bed of the stream, and owing to the character of some of the materials encountered it was deemed necessary to make further investigations along these lines. Consequently an additional set of borings, consisting of three parallel lines 140 ft. apart with the borings spaced 100 ft. in the lines, were made to determine the location of the dam. Instead of making wash borings the samples were obtained by simply driving a standard weight 1¼ in. wrought iron pipe to a penetration of 2 ft. to 3 ft., and then withdrawing the pipe and taking the samples. These borings were made with regular well-drilling derricks and engines. The pipe was arranged near the upper end with a collar to receive the blows from the hammer. The hammer consisted of a cast iron weight with a hole through the center so as to slide on the pipe, the rope lifting the hammer being carried over a sheave at the top of the derrick and down to a nigger-head on the engine. The operator by alternately tightening and slacking the rope obtained any intensity of blow desired.

The samples secured in this way more nearly represented the character and consistency of the materials encountered, but still left much to be desired. However, the results obtained from these borings were used in determining the design of the foundations, cut-offs, etc. The test pits dug on the river bank gave little indication of the consistency of the same materials under the bed of the stream, but the digging of test pits in the river was impracticable, owing to the difficulty of keeping out the water and also to the lack of time.

GENERAL DESCRIPTION OF THE PLANT.

At the site selected for the dam, the river is divided by an island of considerable size. (Fig. 1.) As the channel on the north side of the island was the narrower and deeper channel, and on account of the transportation facilities, camp location, etc., it was decided to build the power house across the north channel and keep the spillway entirely in the south channel. This arrangement results in keeping the flood waters out of the tailrace except for the backwater from the foot of the island.

The permit for building the dam required that space should be appropriated and arrangements so made that a navigation lock could be built at any time that the War Department might con-

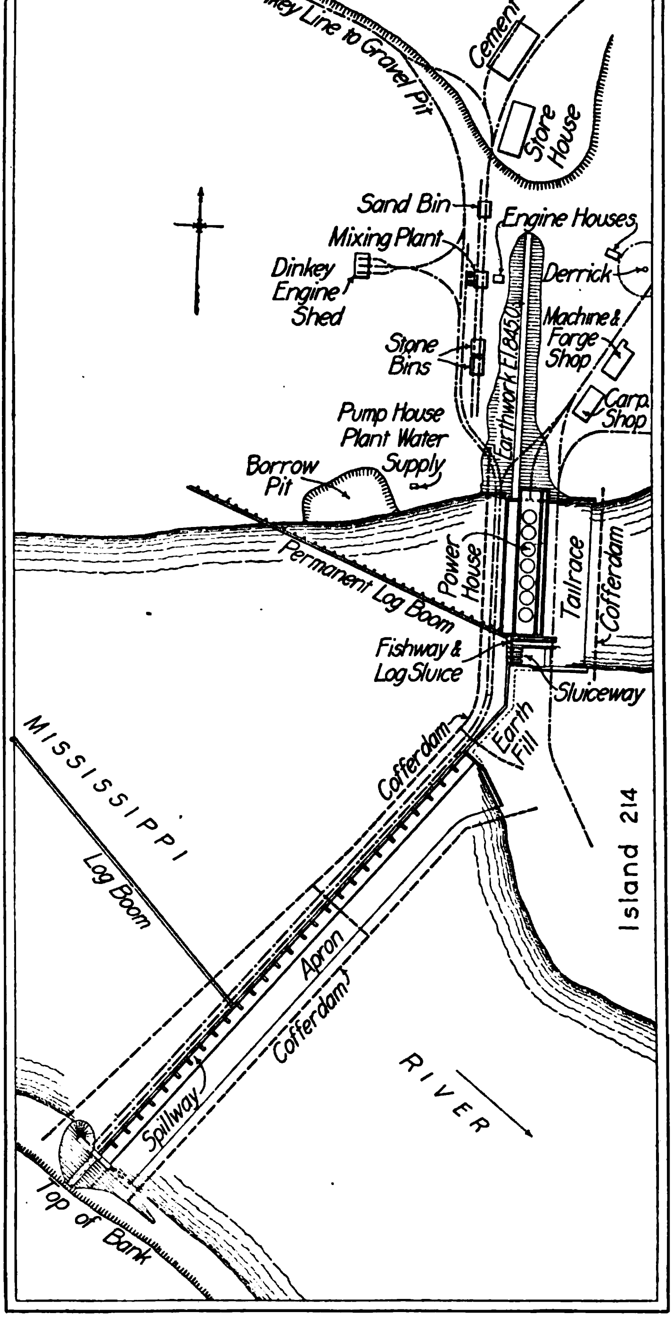


Fig. 1.—General Plan of Coon Rapids Plant.

required the installation of a fish-way.

The space selected for the lock is at the extreme south end of the dam, where a heavy abutment and wing wall was built at the end of the spillway and located at about the extreme low water line of the river. From this abutment to the high bank, a distance of about 80 ft., an earth embankment with a concrete core wall was built; the core wall having joints so that a section of it can be readily removed without disturbing the balance of the structure. From this south abutment the spillway of the dam, which is of the regular O. G. section (Fig. 2), runs for a distance of 1,005 ft.; and is surmounted by piers dividing it into 28 openings each of 33 ft. net length. These openings are controlled by Tainter gates, which are operated from the bridge carried on the tops of the piers. From the north abutment of the spillway at the south side of the island to the north side of the island is a retaining section of dam 178 ft. long, and in this part of the structure there is an angle in the alignment.

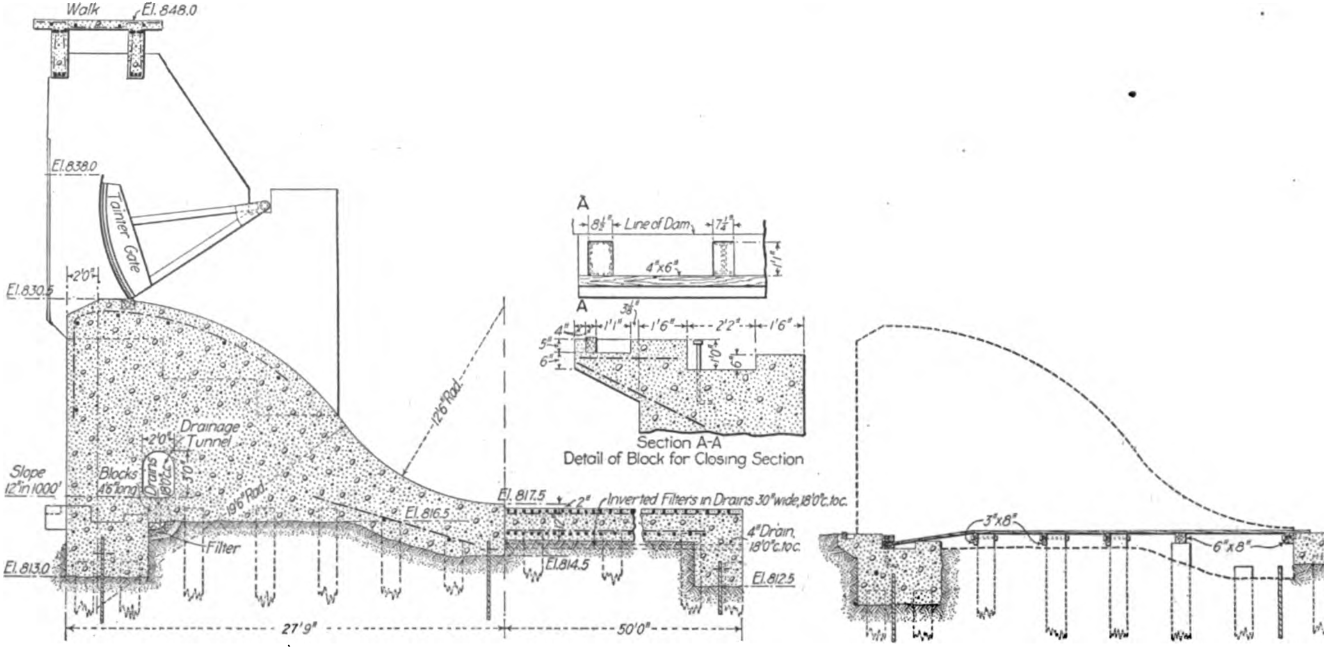
Adjacent to the north end of the retaining section and occupying a width of 62.5 ft. there are, in the order named, four sluice gates, a log sluice and a fish-way, the fish-way being adjacent to the south end of the power house. The power house, 255 ft. long, occupies the remaining space to the north bank of the river, where a heavy retaining wall protects the shore; and from this point, a distance of 490 ft., there is an earth embankment with concrete core wall. The total length of the dam, power house, and embankments is 2,070 ft.

In determining the layout of the power plant, horizontal units were considered, but owing to the low head and the requirement for a unit of large capacity, this arrangement was impracticable, and it was finally decided to install a vertical single runner unit with the umbrella type generator. The weight of the rotating parts is carried by a roller bearing supported on the top of the generator.

The foundation of the power house is constructed for seven units, five of which comprise the initial installation. The wheels, which are 12 ft. 8 in. diameter on the discharge ring, are set in scroll cases, the scroll cases and draft tubes being built of concrete without lining. The cast iron pit rings were grouted in after the scroll cases were completed and the form removed. (Figs. 3 and 4.) The scroll case inlet is divided by a central pier into two openings 18 ft. deep by 14 ft. 6 in. wide, and is controlled by Stoney gates. Stop-log grooves are provided upstream from the gate grooves.

The trash racks are continuous for the whole length of the forebay, are inclined at about 70° to the horizontal, and have a vertical wetted depth of 25 ft.

The superstructure is a steel frame with brick walls and a gravel roof.



Spillway Section

Temporary Floor of Open Section

Fig. 2.—Cross-Section of Spillway Dam, with Details for Openings Through Which River Flow Was Passed.

half gantry serves the forebay for handling the Stoney gates.

CONSTRUCTION CAMP AND PLANT.

Starting near the north end of the dam and extending some distance upstream is a bench or terrace from 15 to 20 ft. high. This bench, being sandy and covered by a grove of oaks, furnished an excellent location for the construction camp, which was planned for the accommodation of at least 800 men. The camp was laid out with streets and was provided with water works, sewerage, and electric lights. A number of cottages were built for the use of foremen and mechanics who had their families with them, but the other workmen were taken care of in bunk houses.

The buildings were all light frame structures covered with ship lap and heavy roofing paper, and owing to the severity of the climate the bunk houses which were occupied during the winter were heated with hot-air furnaces. The buildings were all well separated so as to reduce fire risk, and, with the exception of the superintendent's office, the hospital, the store and the foremen's and engineers' bunk houses, they were one-story structures. The camp was supplied with a club and a moving picture show, and on account of the large number of children in the camp the county of Anoka opened a public school for them, the building being furnished by the Northern Mississippi River Power Company.

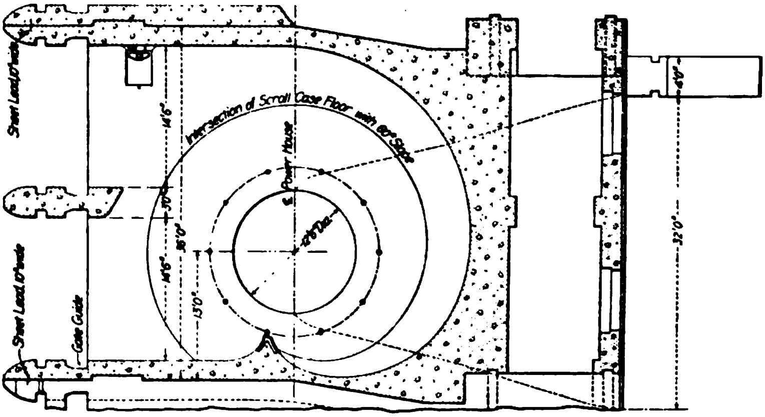
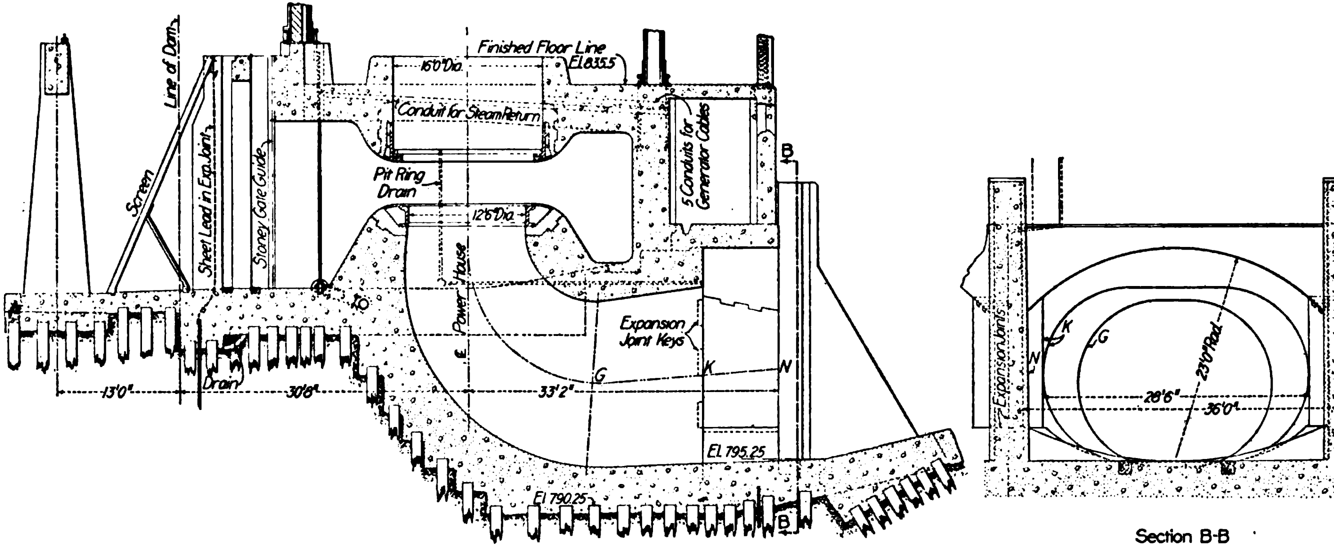


Fig. 3.—Sectional Plan of Intake and Scroll Case of Coon Rapids Development.

The water supply for the camp was obtained from a 4 in. artesian well 210 ft. deep, but, as the water did not flow with sufficient pressure for distribution through the camp, pumping was necessary.

The electric current for lighting and general construction purposes was obtained from Minneapolis over the permanent transmis-



Section B-B

Fig. 4.—Sectional Elevation of Power House Substructure on Center Line of Main Unit and Front View of Draft Tube.

could be secured and delivered on the ground.

The Minneapolis & Northern Railway, an interurban line between Minneapolis and Anoka, passes within about one-half mile of the power house. Arrangements were made with this company for delivering materials on the work, and a spur was built from their tracks to the power house site for this purpose. This track is to be maintained for use in receiving supplies and additional equipment, but a track for construction purposes only was built from this spur up on the terrace to the cement storage house (Fig. 1), and thence on a trestle to the sand and stone bins.

The general arrangement of the construction plant is clearly illustrated by Fig. 1.

The sand and stone was dumped from the trestle into the bins. The platform of the mixing plant was under the trestle but higher than the bottoms of the sand and stone bins; the two 1½-yard motor-driven cube mixers were set so as to dump directly into cars on the track which ran out on a trestle along the upstream side of the dam. A steam hoist, operating dump cars on inclined industrial tracks running under the bins, brought the sand and broken stone to the mixer platform. The cement was brought from the storage house on push cars operating on the high trestle. The cement was taken from storage on the opposite side of the house from the receiving track, thus readily permitting the use of the cement in the order in which it was received.

The trestle along the back of the dam carried three tracks. One of these, a standard gage track, was for the operation of a 12-ton locomotive crane, which was intended principally for handling forms and Tainter gates but which, on account of its convenience, was probably used more for other purposes. The other two tracks were 3-ft. gage and were used for placing concrete. One of these tracks was formed by placing a third rail 3 ft. from one rail of the standard gage track. The narrow gage tracks were connected at several points by crossovers, and the locations of the crossovers were changed as the work progressed to facilitate the handling of the concrete.

All concrete for the spillway and the lower parts of the retaining dam and power house substructure was taken from the mixers in side dump cars with dinkey engines and was dumped into chutes, which conveyed it directly into the forms. For the spillway apron the concrete was run into a hopper by chutes from the trestle and distributed with buggies. Where the forms were so high that the chutes could not be used, the concrete was taken from the mixers in cylindrical buckets on flat cars and the buckets were swung into position for dumping by the locomotive crane or a derrick.

A good quality of sand for the concrete was obtained on the ground but the broken stone had to be brought from Minneapolis.

shops were run by electric motors.

All piling was driven with No. 2 Warrington steam hammers; the leads and turn tables were built on the ground.

FOUNDATIONS.

Probably the most interesting feature of this construction is the foundations.

The formation is glacial drift and the borings indicated a great variety of materials, including boulders, clay, gravel and many grades of sand. Except for the clay beds, the materials were principally in small deposits or pockets and without any special order. This was particularly true of the sand.

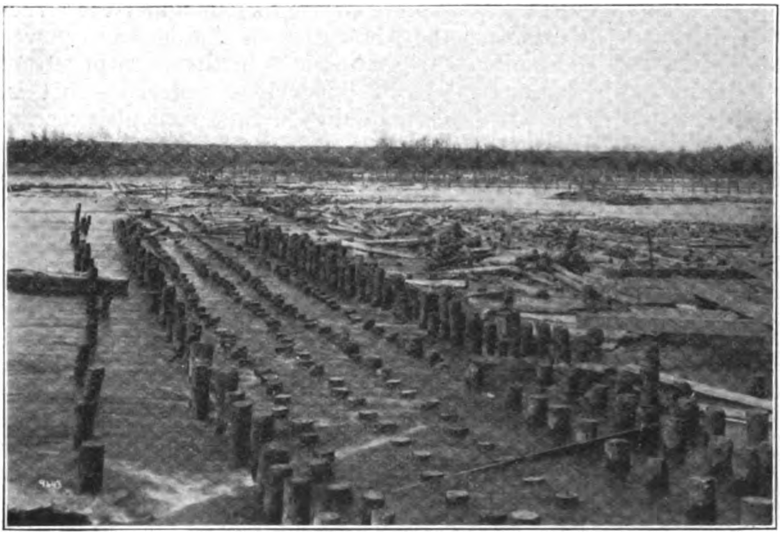


Fig 5.—Piles for Spillway Dam.

The most extended and homogeneous deposits encountered were two clay beds. The lower deposit is very compact. In places it seems like an indurated clay and is hard to penetrate but it carries a large percentage of sand and if a lump of it is dug out it is easily broken up by hand. The upper surface of this deposit has a dip to the north, being some 15 ft. above low water at the south bank and 60 ft. to 70 ft. below the bed of the stream at the north bank.

The other clay bed referred to lies above and in some places in contact with the material just described but is of a very different nature and in extent seems to be confined, at the site of the plant, to the head of the island and the north channel of the river. This is a soft clay, carrying a considerable percentage of very fine sand.

capillarity.

From the information obtained by the test pits and borings it was realized that this soft clay deposit in which the power house excavation would have to be made would be difficult to handle, especially so as the excavation had to go some 25 ft. below the bed of the stream. It was proved afterwards, however, that the information obtained from the borings and test pits really gave little indication of the true character of the material and the difficulties which would be encountered in making the excavation.

Owing to the great variety of materials encountered, it was determined that the whole structure should be carried on piles, so as to insure, as far as possible, against unequal settlement.

Provision against the possibility of a blow-out under the structures was made by enclosing the whole area of the dam and power house with steel sheet piling, driven to such depths as to penetrate well into what was assumed to be impervious material,—that is, impervious under the pressures obtaining in this particular case.

To prevent upward pressure on the base of the dam, a drainage tunnel was constructed throughout its whole length, which discharges into a sump in the power house. This tunnel is connected by vertical risers with a blind drain just back of the upstream cut-off wall. The blind drain is constructed on the principle of a water filter turned upside down, the idea being that if any water gets past the upstream cut-off it will find its way into the tunnel without carrying any solid matter with it, and from there it will pass into the sump, where it can be pumped out in time of high water or where it can flow out by gravity under normal conditions. This tunnel also provides a means of inspection and of locating leaks in case any should develop. Up to the present time there has been little leakage into the drainage tunnel and the leakage will probably lessen rather than increase.

In order to determine the length and number of piles to be used and the safe working loads per pile, a line of test piles was driven across the river at the dam site, and from the data thus obtained the piling plan was worked out.

After a careful study of the situation, it was decided to allow a working load of only ten tons per pile under all of the structures except the power house. This value was obtained usually with piles 20 to 30 feet long and, of course, piles could have been readily obtained and the spacing so arranged as to have allowed a higher limit of load on each pile; but the low limit was used in order to get a closer spacing of the piles and thus insure a more uniform distribution of the loads. In all there were 12,000 piles driven for the permanent structures and 3,000 for cofferdams and other temporary structures.

In driving the piles careful watch was kept of the penetration, and the bearing value of the pile was figured by the get the desired bearing value, one or more additional piles were driven adjacent to it.

Under the spillway part of the dam seven lines of piles were used and so arranged as to give as nearly uniform loads as possible on all the piles. (Figs. 2, 5 and 6.)

At the south end of the spillway, where the compact clay rises to the bed of the stream, it was found impossible to drive either steel sheet piling or round piles, and at this location, instead of sheet pile cut-offs, concrete walls were substituted, the concrete being placed in the trenches without forms.

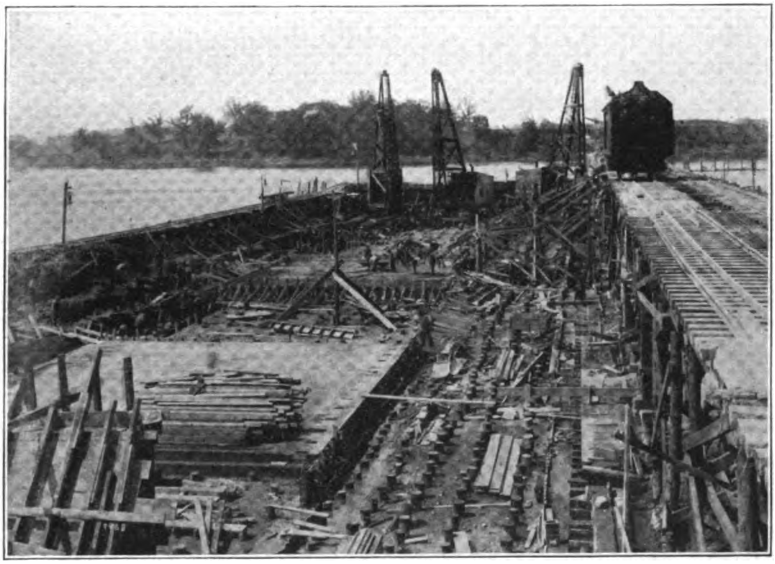


Fig. 6.—Section of Spillway Foundation Ready for Forms.

Four 54-ft. sections of the part of the spillway dam enclosed by the first cofferdam were omitted for passing the water while the remainder of the structure was being built. To have put in a concrete protection over the earth in these openings would have required a thin slab of concrete as a capping for the piles and a horizontal joint through the dam. Both of these features were very objectionable and as an alternative a temporary timber floor was constructed, as shown in Fig. 2. This floor consisted of two courses of one-inch boards, spiked to timbers bolted to the heads of the piles. To prevent damage from logs and drift the upstream ends of the boards were held between two timbers securely bolted to the concrete block which capped the steel sheet piling, and the downstream ends lapped over on the concrete apron. This arrangement was inexpensive and very satisfactory.

December, 1914

used. Under the sluice gate structure, the log sluice and fishway, the same general arrangement was used but so modified as to keep approximately the same load per pile.

Many obstacles such as large boulders, logs and old cribs, which had been used in the logging operations on the river, were encountered in driving the piling; and in a number of cases these obstacles had to be removed by the use of powder. The steel sheet piling would usually cut through the logs without much trouble, but in one case, where an old crib was encountered, the lower end of a sheet pile was doubled over and came back up to the surface as the driving continued.

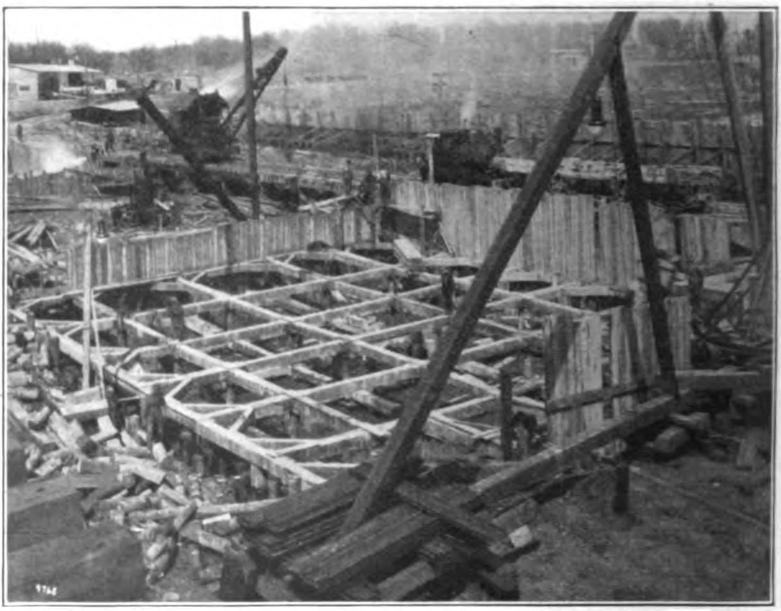


Fig. 7.—Bracing for Power House Excavation Units 6 and 7.

As no considerable depth of excavation was necessary under the dam, there were no special difficulties encountered in this part of the work; but in the power house excavation the unstable character of the clay, which has previously been referred to, made it necessary to adopt extra precautions. In carrying out this part of the work it was considered best to make the excavation in sections and not open up the whole area of the power house at one time. Following out this line, the excavations for the two units at either end of the power house were first started, leaving the three center units for the final excavation.

In the first two excavations (Fig. 7), 3-in. sheeting was driven always a little below the bottom of the excavation. The sheeting was braced with 12 in. by 12 in. timbers, spaced 8 ft. in both directions horizontally and about 4 ft. vertically. This method proved fairly satisfactory, but there was some difficulty encountered due to the sheeting pushing in at the bottom before enough excavation was completed to put in a new set of braces, and in this way the excavation was gradually reduced in area as it increased in depth. This, however, did not result in any serious trouble, since considerable clearance was allowed in laying out the excavation area. The greatest difficulty encountered in this method of carrying on the excavation was due to driving the piling after the excavation was completed. This was done because it was considered impossible to follow the piles down to the required depths and prevent bunching and also to determine what would be the bearing value of the piles driven in this way.

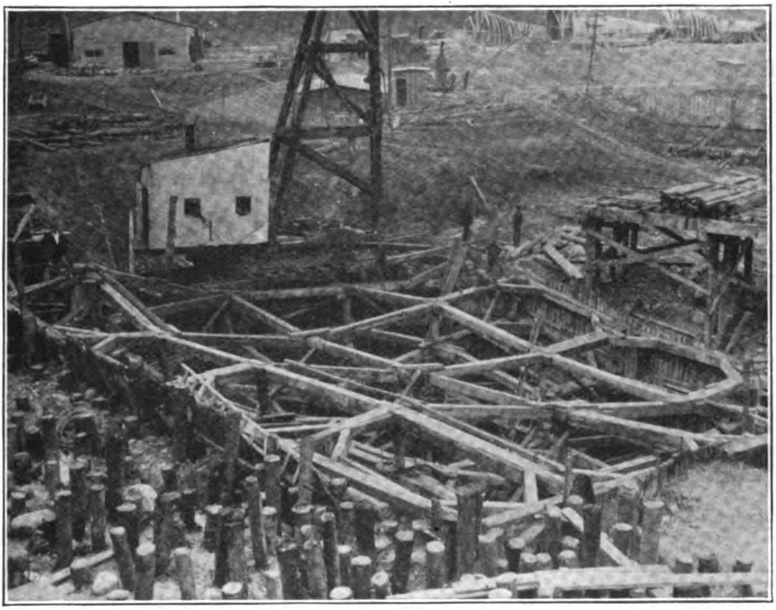


Fig. 8.—Bracing for Power House Excavation During Driving of Piles, Units 6 and 7.

Driving the piles after the excavation was made resulted in the heaving of the bottom and the distorting of the bracing. (Figs. 8 and 9.) The work, however, was carried through to a successful finish and this was accomplished by tying the bracing down to the heads of piles already driven. This did not entirely stop the distortion and buckling of the bracing but did prevent it from collapsing.

that the bottom had lifted about five feet, so that this amount of excavation had to be done over. Wherever water flowed over the clay it eroded very rapidly and became liquid mud and as it seemed impossible to stop all flowing water, this also greatly increased the amount of excavation.

With the main timbers spaced 8 ft. centers in both directions in the first two excavations, there was not room to set up the draft tube forms. The plan adopted was to so rearrange the bracing, as soon as the excavating and driving of piles was completed, as to clear the forms for one unit and allow the foundations to be built up to the bottom of the scroll cases. (Fig. 10.) This plan resulted from the supposition that the arrangement of bracing which would allow room for setting up the forms would not be strong enough to stand the pressures caused by the vibrations due to driving the piling. The experience in carrying out the work proved this supposition to be correct.

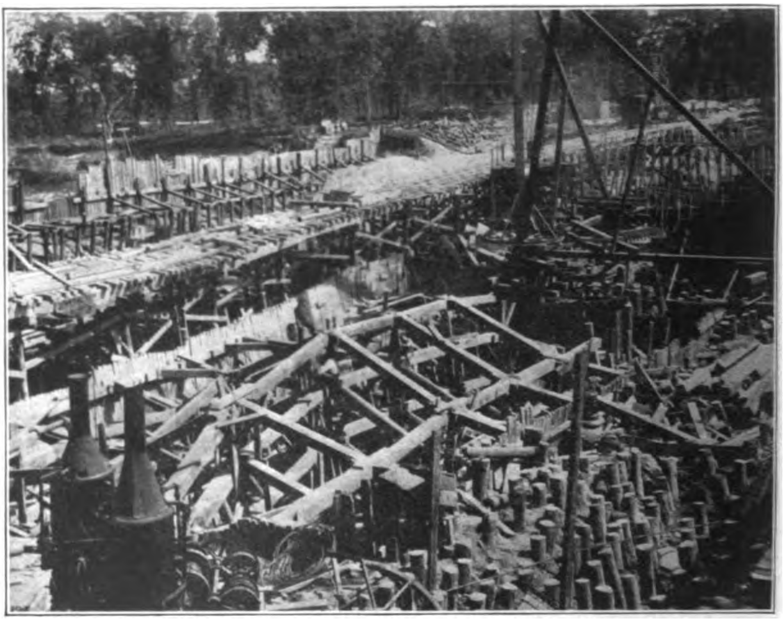


Fig. 9.—Bracing for Power House Excavation Piling Completed, Units 6 and 7.

When the excavation was started for the three intermediate units, it was decided to change the plan of procedure and make as much of the excavation as seemed safe without sheeting and bracing, after which the sheeting was driven to the full depth required around the area to be excavated. Then the piles were piles of greater length than necessary for the structure were used, since it was found impracticable to drive with a follower much to exceed ten feet, and the extra length of pile was cut off after excavation was made.

When the piling was completed, the excavation was carried down and the bracing as originally placed was so arranged as to permit of setting up the forms. This latter method proved in many respects more satisfactory than the former, but a great deal of the trouble in the first excavations would have been obviated had the sheeting been driven to the full depth before the excavation was started, instead of being driven as the excavation was carried down.

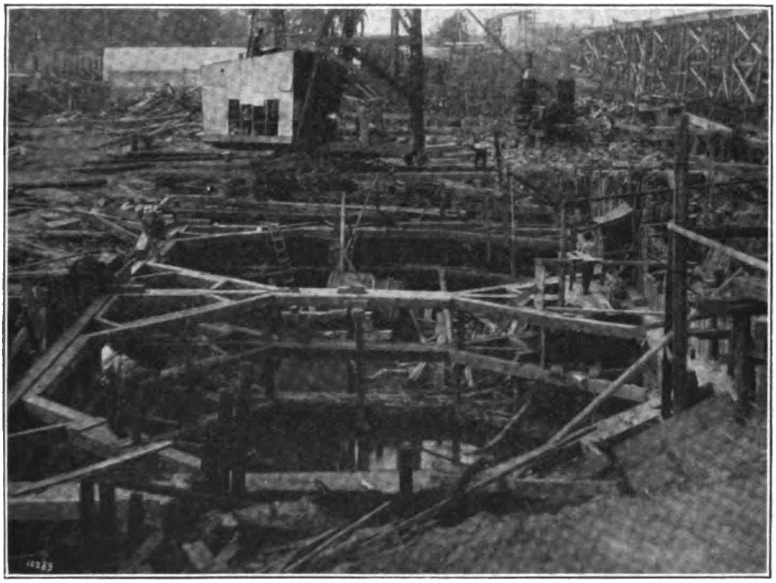


Fig. 10.—Bracing for Power House Excavation Rearranged for Setting Draft Tube Forms, Units 6 and 7.

The enormous pressures which had to be taken care of in bracing the excavation were very clearly demonstrated in making the excavation for the three intermediate units, where in many cases with three 12 in. by 12 in. timbers fastened together they buckled to such an extent it was sometimes feared that they would break and extra braces had to be put in to make it safe.

As it was found that the piling for the power house could be driven to refusal, it was decided to increase the allowable loads per pile to 25 tons, but even with this allowable load under some parts of the structure the piles had to be spaced about as close as it was practicable to drive them.

December, 1914

the horizontal forces so as to prevent movement of the structure downstream. This was done by driving inclined piles, but, as only a few inclined piles could be driven in the area under the main part of the structure, owing to the interference of the bracing and the vertical piles, buttresses were carried downstream between the draft tubes, and each buttress rests on a cluster of 32 inclined piles driven to refusal. (Fig. 4.)

After the structures were completed, careful observations were made to see if any movement occurred, but up to the present time no movement of an appreciable quantity has taken place. This fact in connection with accuracy in locating the scroll cases has made it possible to set all of the units to exact line.

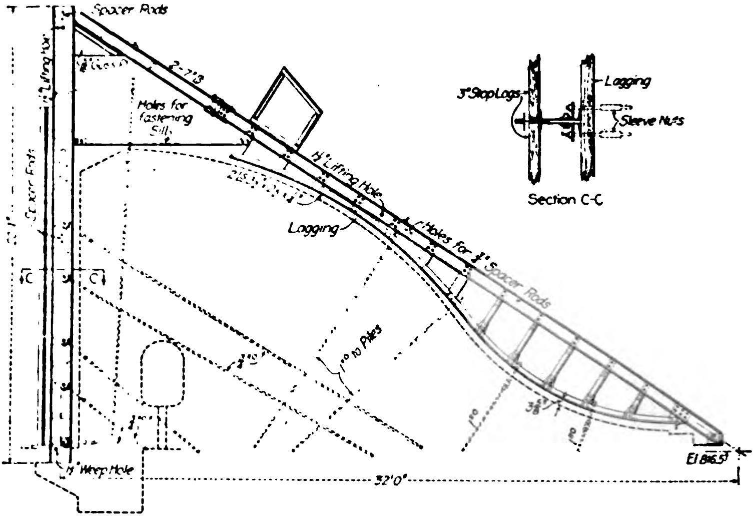


Fig. 11.—Steel Ribs for Spillway Forms.

FORMS.

Another feature of this work which is worthy of notice is the collapsible forms for the dam, the scroll cases and draft tubes.

The forms for the dam (Figs. 11 and 12) were made of sets of vertical and inclined steel ribs with horizontal wooden lagging. The vertical ribs, which were built up of two 12-in. channels spaced ¼ in. apart back to back and riveted together through the webs, were used on the upstream side; while the inclined ribs, made up in the same way but of 7-in. channels, were used on the downstream side. The inclined and vertical ribs were bolted together by a gusset plate connection at the upper ends and were held in place longitudinally of the dam by bolts and pipe separators. The two vertical ribs at each end of a form unit were fastened rigidly to-forms when being erected. Attached to the under side of the inclined ribs by angle iron furring were pairs of angles bent to the proper curvature for the downstream face of the dam. The ribs were spaced 4 ft. 2½ in. on centers and one form unit embraced a section of the dam 54 ft. long.

The lagging used was 3⅝ in. thick, finished size, by about 4 in. wide, and approximately 13 ft. in length. Malleable iron clips were used to secure the lagging to the ribs. These clips were of proper form to fit around the flanges of the ribs and leave space for small wooden wedges. The clips were fastened to the lagging with lag screws, and as the lagging was laid in place, the wedges were driven in between the clips and the flanges of the ribs. This method of attaching the lagging to the ribs not only facilitated the assembling of the forms but also their removal after the concrete was set.

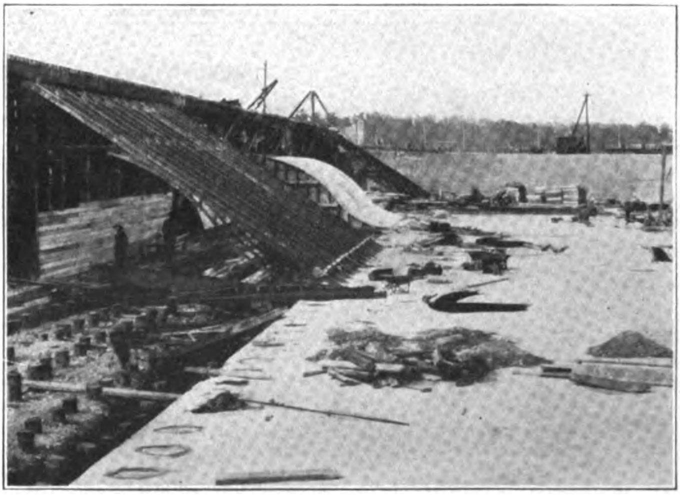


Fig. 12.—Spillway Forms in Course of Erection.

In order to reduce the cost and facilitate the work of making the final closure in the dam, the forms were designed to take the place of a cofferdam in these openings. This was accomplished by framing part of the vertical ribs with web plates projecting far enough on the upstream side to receive light angles and thus, in connection with the upstream flange of the rib, form a groove to hold stop planks.

To hold the lower ends of the ribs in proper position, it was originally intended to build, in place, small concrete blocks, each containing a pocket to receive the foot of a vertical rib, and to leave pockets near the upstream edge of the apron to receive the feet of and proved satisfactory, but before any of the blocks were built it was realized that a timber, with wooden strips spiked to it, would hold the feet of the vertical ribs just as satisfactorily and cost less: and this method was pursued except in the openings left for passing the water during construction. In these latter openings (Fig. 2) a continuous concrete sill was built as an integral part of the block of concrete in which the heads of the steel sheet piles were embedded. Pockets were left in this concrete sill to receive the ribs so that they could be set in place and accurately spaced in the running water. A timber sill was embedded in the concrete sill to receive the stop planks.

When the time came for making the final closure in the dam, all of the ribs were set up and secured in place by bolting to the heads of the foundation piles or to the Tainter gate sills in the adjacent finished sections of the dam, before any of the stop planks were put in. (Fig. 13.)

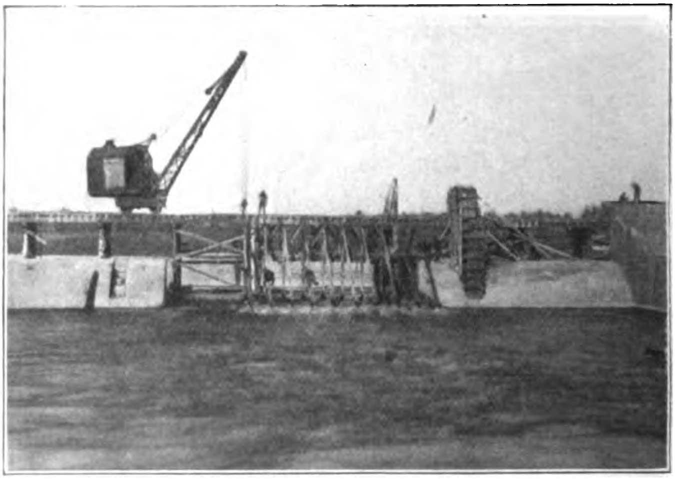


Fig. 13.—Setting Form Ribs in Running Water.

On the upstream side the end ribs of each form unit were so arranged as to bolt to the face of the concrete in the adjacent finished sections of the dam, with a thin wooden block between the rib and the concrete to form a tight joint. The space between the stop planks and the lagging furnished a place for any water which passed the stop planks, to accumulate and to be pumped out, but pumping from this space proved to a large extent to be unnecessary, as the stop planks were so tight that the leakage was not sufficient to cause trouble in most cases.

Owing to the fact that the final closure had to be made in consisting of timber cribs with sheeting, had to be used on the downstream side instead of dams made with sacks of sand as was first planned.

The method used for stopping off the water proved very satisfactory, as did also the arrangement and design of the forms.

For convenience in construction the spillway dam was divided by expansion joints into sections 54 ft. long and these joints were so arranged that half of the sections have two Tainter gate piers, while the alternate sections have only one pier each. The sections which were left for the final closure were the sections having only one pier. In all cases notches were left in the top of the dam to receive the piers and the piers were built after the body of the dam was completed.

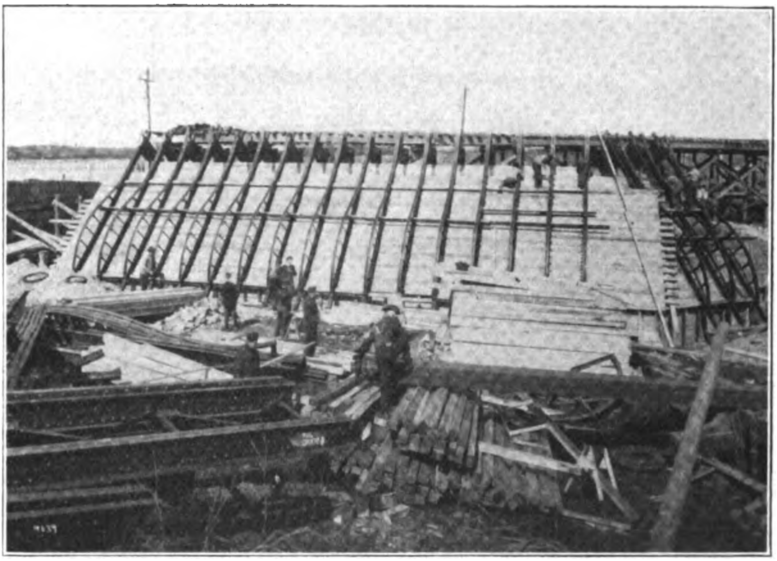


Fig. 14.—Ribs for Spillway Forms in Use on Retaining Dam.

As it was intended under some conditions to fill the forms for the dam at the rate of at least 4 ft. per hour, they were designed to sustain a pressure of 1,000 lb. per sq. ft. This pressure was determined for temperatures around 60 deg. F., from experiments made by Major Shunk, U. S. Army, at what is known as the High Dam on the Mississippi River at Minneapolis. In order to secure the forms from being lifted by the upward pressure of the concrete on the curved part, the ribs were secured by rods to the heads of the piles.

By making a horizontal joint in the retaining dam 5.5 ft. below the full reservoir level and building the upper part with separate forms for the lower part of the retaining dam. This modification consisted in making joints in the inclined ribs, so as to reduce their length, and attaching projecting plates to connect with the gusset plates at the tops of the vertical ribs. For use on the retaining dam the inclined ribs were turned over so that the shoe would have a better bearing, and as it seemed probable that the furring and curved angles might be troublesome these parts were bolted to the ribs so as to be readily removed. This provision proved to be unnecessary. (Fig. 14.)

The draft tube forms (Figs. 15, 16, 17 and 18) were built up on a central rib or keel. Transverse ribs were made up of two or more thicknesses of 1¼-in. plank and spaced not to exceed 2 ft. at the outer edge where the lagging attached. These transverse ribs were made in quadrants, and were bolted by angle iron clips rigidly to the central rib, but on the horizontal axis a 3-in. space was left for wedges so that in removing the forms the upper quadrants could be dropped 3 in. and thus be loosened sufficiently to permit of being removed from the draft tubes. Three or more of the quadrants of adjacent ribs were fastened together with cross bracing and after being lagged composed one section of the form.

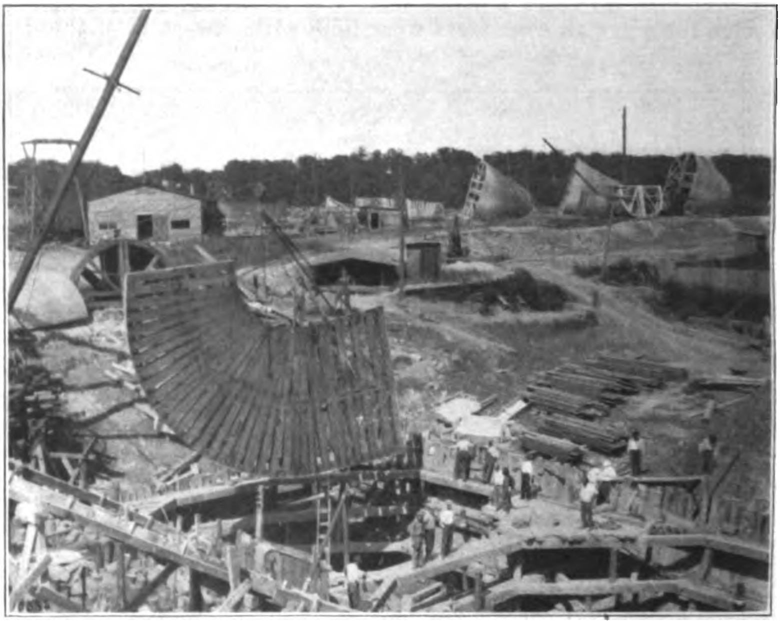


Fig. 15.—Central Rib of Draft Tube Form.

The complete draft tube form was composed of sixteen of required only two days to take it apart, move it a distance of about 300 ft. and reassemble it in final position for concreting.

The scroll case forms (Fig. 19) were built on practically the same plan as the draft tube forms, but in this case the keel or central rib lay in a horizontal instead of a vertical plane, and as this rib was placed at the horizontal center line of the wheel gates, the

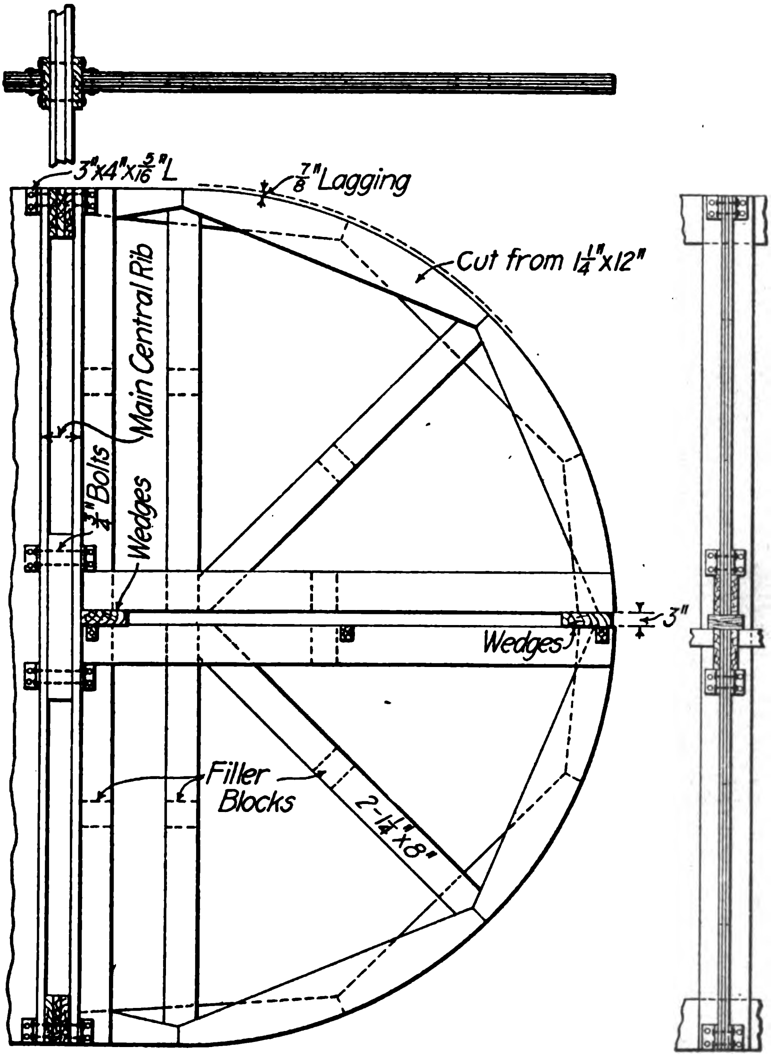


Fig. 16.—Transverse Rib for Draft Tube Form.

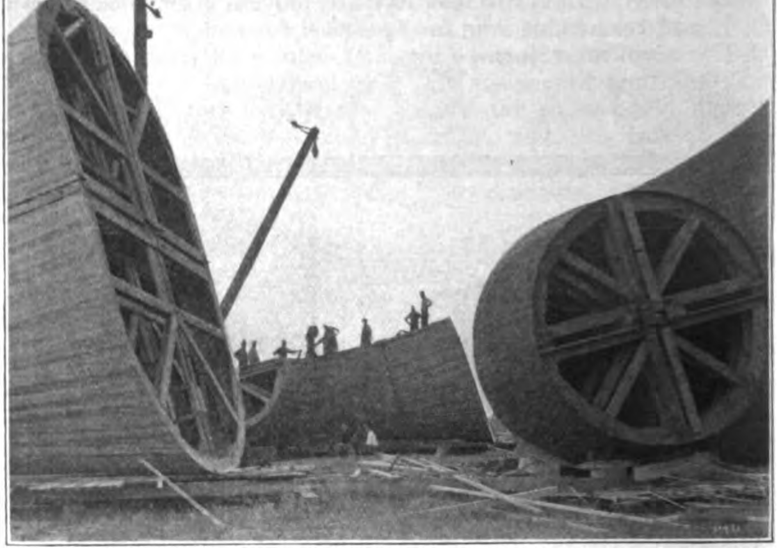


Fig. 17.—Completed Draft Tube Forms.

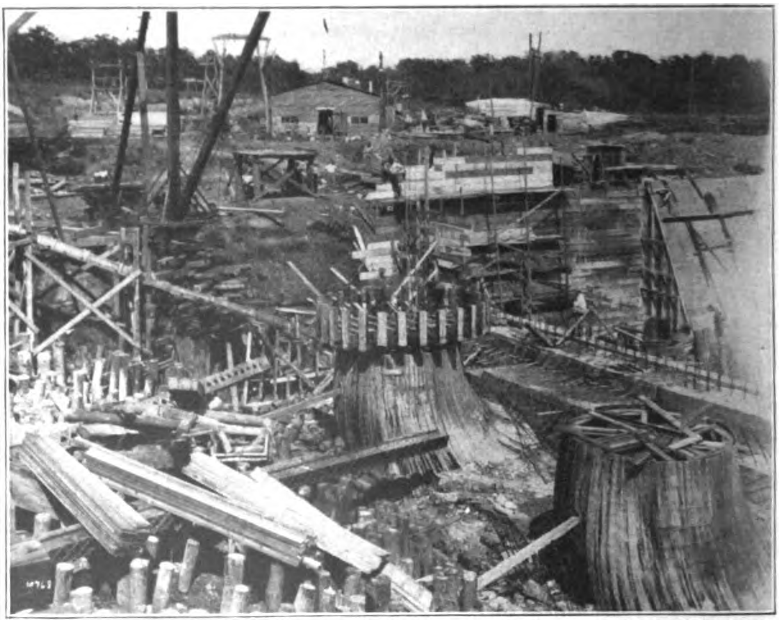


Fig. 18.—Draft Tube Forms in Position for Concreting.

the part above.

The transverse ribs and the sections of the form were made up in the same way as for the draft tube forms and were bolted to the central rib by angle iron clips; wedges were placed under the upper sections.

A grill work of 8 in. by 8 in. timbers placed directly on the top rib of the draft tube form carried short vertical posts, which supported the central rib of the scroll case form. On top of the central rib rested a short cylinder, so to speak, made of two circular ribs with posts between; to these posts and the posts supporting the central rib were attached the transverse ribs of the forms. Lagged cylinders, which were divided into quadrants, separated by narrow parallel sections and wedges, completed the wheel pit forms.

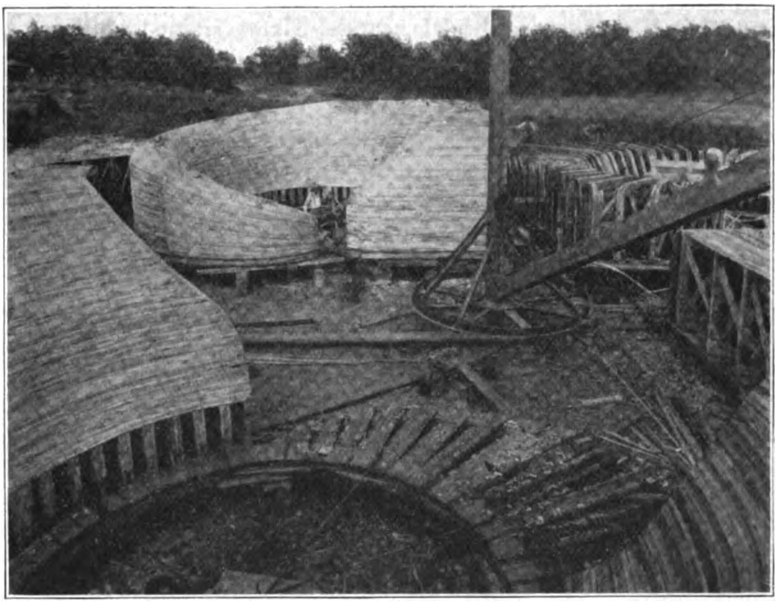


Fig. 19.—Scroll Case Forms.

This method of constructing the draft tube and scroll case forms proved to be eminently satisfactory, as the forms were easily assembled for concreting, were readily removed from the concrete, and in the process were damaged very little. In many cases, however, the sections were so large and heavy that it required considerable ingenuity on the part of the workmen in removing them from the concrete to transport them to points where the derricks could lift them. Smaller sections would have made this part of the work considerably easier but, on the other hand, the assembling

TAINTER GATES.

A detail of this plant which is of unusual design is the Tainter gates. (Fig. 20.) These gates have a length of 33 ft. and sustain a water pressure due to a head of 7.5 ft.

The especially unusual feature of the gates is the omission of all cross bracing. They are built up of **I** beams which span the opening, these being attached to plate girders at the ends. From the girders struts extend to the pins which support the gates and on which they hinge. Between the beams and the struts gusset plates are inserted in lieu of the usual cross bracing. The cover plates are riveted to the flanges of the **I** beams. Gates framed in this way will require somewhat more metal than if the cross bracing is used and will possibly cost slightly more, but they have the advantage of being far less liable to damage in case they are overtopped by a flood, due to the negligence of the attendant or to accident which might prevent them being opened at the proper time.

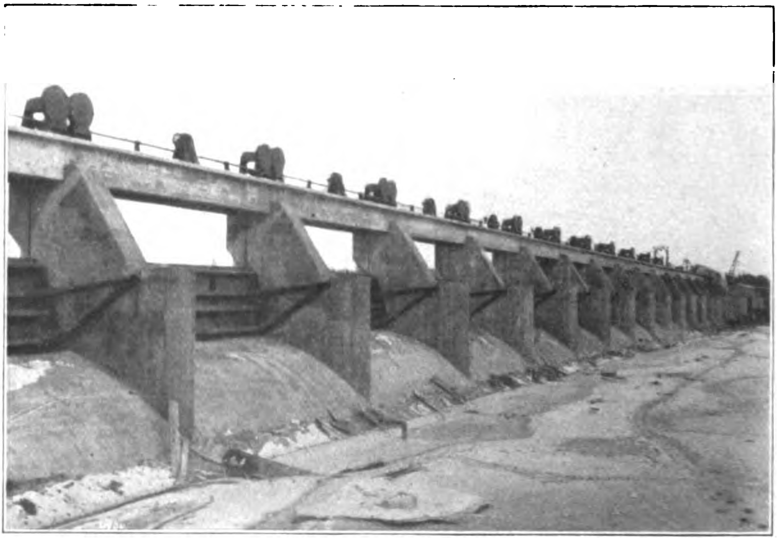


Fig. 20.—Spillway and Tainter Gates.

As it seemed practically certain that there would be unequal settlement in the various sections of the spillway, the bearings of the gates were arranged to be adjustable. This was accomplished simply by slotting the holes for the anchor bolts which secure the bearing to the concrete and added little, if anything, to the cost. While this provision seemed absolutely essential when the gates were designed, as yet no readjustment has been necessary.

The gates are made water tight on the bottoms and ends by the use of rubber belting. The strips on the ends bear against the piers, while the strip on the bottom is folded and so adjusted that the fold bears on the gate sill. The leakage around these gates is very small and probably would have been less but the gates were placed in cold weather and ice interfered with proper adjustment of the belting.

The hoists for these gates were specially designed by the Whiting Foundry Equipment Company after specifications and suggestions by the writer. These hoists consist of two stands with chain drums driven by worm gear. The stands are placed close to the ends of the gates and the worms are driven by a line shaft in one piece; the operating stand is placed at the center between the drum stands. The hoists are arranged for hand or electric motor operation. Up to the present time all the operation has been by hand and without any difficulty; one man is able to raise and lower the gates with ease.

The main object in having motor operation for the gates would be in emergency cases when it was desired to open the gates quickly, and for this reason if a motor is ever used it is the intention to have it mounted on a truck so as to move along the dam from gate to gate instead of mounting a separate motor on each hoist.

Owing to the ease with which it has been possible to regulate the level of the water in the reservoir by the manipulation of the gates, it seems that the installation of a motor to take the place of hand-operation would be unnecessary.

HYDRAULIC AND ELECTRICAL EQUIPMENT.

The 15,000 h. p. total generating capacity provided for in the Coon Rapids station was determined, principally, from a study of the stream flow data for the years 1900 to 1910 inclusive as recorded by the St. Anthony Falls Water Power Company of Minneapolis, and on the assumption of operating on a 100% load factor basis insofar as the water is available; or, in other words, to use the water as it comes, up to the full capacity of the equipment. From these data it was estimated that the average annual output of the Coon Rapids plant would be 40,000,000 kw. h.

About the first of the current year the data for the discharge of the Mississippi River at Lock & Dam No. 2, as recorded by the U. S. Government Engineers, were obtained for the years 1905 to 1913 inclusive. An analysis of the possible output of the plant in the light of these data shows that an annual average of 64,000,000 kw. h. may be expected from the complete installation of seven units and 52,000,000 kw. h. from the initial installation of five units, and this, notwithstanding the fact that the data used cover three of the dryest years on record for Minnesota.

The generating units are of the vertical type, each consisting of an Allis-Chalmers single runner Francis turbine, direct connected and oil pressure governor.

The turbine runner, having a mean diameter of 8 ft. 6½ in. and a diameter over the discharge ring of 12 ft. 8 in., is set in a concrete scroll case with cast iron pit rings.

The wheel gates, which control openings 54 in. high by 13 in. wide, are of the swivel type with exterior operating ring and links.

The rotating element of the machine is carried by a roller thrust bearing, which rests on the upper spider of the generator, and the length of the shaft from the center of the runner to the top of the roller bearing is 21 ft. 6 in. A water lubricated lignumvitæ guide bearing is carried by the upper cover plate of the turbine, and an oil-lubricated guide bearing is carried by the upper spider of the generator just below the roller thrust bearing. The shaft has a flanged coupling 3 ft. 7 in. above the lower guide bearing.

The lubrication of the roller bearing and the upper guide bearing is secured by a unit oiling system. The oil filter, storage tank, and circulating pump are located in the wheel pit. The motor-driven rotary circulating pump is mounted on the oil tank and forces the oil up to the bearings; the return of the oil to the filter is by gravity.

The governor head and governor oil pump are driven by belts from a counter shaft, which in turn is driven by bevel gears from the main shaft of the turbine.

The generator is a 1,625 kv-a., 2,300-volt, 62 r. p. m., 3-phase, 60-cycle machine, the rotor of which is 17 ft. 4 in. in diameter.

The maximum load on the roller bearing, due to the weight of the rotating parts and the downward thrust of the water, is 170,000 pounds.

The excitation of the alternators is furnished by two 300 kw., 720 r. p. m. motor-generator sets.

A 15-panel switchboard provides the means for controlling the station.

For transmission to Minneapolis the current is stepped up to 13,200 volts by two banks of 1,375 kv-a., 60-cycle, single phase, water-cooled transformers.

The exciters, transformers and switchboard are located in compartments on the downstream side of the station and at the same elevation as the floor of the generator room. In a gallery over these compartments are placed the oil switches and lightning arresters.

The transmission line consists of two circuits of 250,000 C. M. solid copper wire, carried on cedar poles with wooden crossarms.

In detail, construction, and general arrangement the entire equipment is so simple, strong and accessible, it is confidently expected that operating and maintenance costs will be very low.

Arrangements are being made at the present time to determine the efficiency of the hydraulic turbines, and from the care and close attention to detail which has been given to the design and construction of this installation, we are anticipating high efficiencies.

W. D. Gerber, M. W. S. E. (Chairman): The paper presented tonight was sent out to the members in "advance" form, hoping that this would promote discussion. The meeting is now open for general discussion.

E. J. Mehren (Editor, Engineering Record): I would ask whether any of the turbines have yet been run at full capacity.

Mr. Link: The first unit was put on the line August 1st, and at the present time four units are in operation. We have been obtaining about 40,000 kw. hours per day from each unit since they were put in operation.

Mr. Mehren: The reason I asked that question was to lead up to another one. What are your observations, so far, of the effect of having the thrust bearing on top of the generator? For instance, how about vibration?

Mr. Link: There seems to be very little vibration, and in general the method has proven very satisfactory. We had a little trouble with the bearing on one generator, but the other bearings have given good satisfaction.

Mr. Mehren: This is a decidedly interesting question, because modern practice seems to point in that direction—putting thrust bearings on top of the generator. I understand that the bearings in connection with a Southern plant are giving very good results, but there has been some dispute about this and the claim has been made that there is considerable vibration. It has been claimed that putting the thrust bearing on top of the generator decreases the amount of concrete in the power house, and because of this decrease considerable vibration is to be expected. Do you think there is anything to that argument?

Mr. Link: In some cases that might be true, but there is so much mass in the foundation below the power house floor, that such a condition is not likely to exist.

Mr. Mehren: Ordinarily that is a point that needs very careful consideration before adopting that type of design. Would the shortening of the shaft have a tendency to lessen the effect of vibration?

Mr. Link: Yes, it probably would.

Mr. Mehren: That probably would offset the smaller mass.

Mr. Link: We have a good deal of mass, necessarily.

Mr. Mehren: That is a very interesting point, and I know hydraulic operators will watch very carefully such plants.

Murray Blanchard, M. W. S. E.: In the Tallulah Falls, Georgia, power plant we installed a similar plant, except that it was a high head development. A load of 75 tons was put on a similar thrust bearing, and I understand the plant is running very smoothly at the present time.

I would ask the author, in connection with the matter of Tainter gates, whether the automatic flash board was considered, as used taken into consideration. The reason it was used on this plant on the high dam was that the flood waters in the deep gorge would come on the dam very suddenly and necessarily there must be very quick action. A constant level within two or three inches can be maintained with these flash boards. I was wondering if such a thing is practical with the conditions you have on the Upper Mississippi.

Mr. Link: That question was considered somewhat, but the conditions on the Mississippi at that point are such that any automatic device fastened to the crest of the dam would be impractical, on account of the logs and ice. We built booms to train the logs to the log chute, but the booms broke the first drive that came down and we had to sluice the whole drive over the dam. The chances are with automatic flash-boards they would be ripped off. We had an arrangement whereby we received information of an approaching flood, 24 hours in advance of the time it reached the plant and thus far we have had little trouble in keeping the level of the reservoir practically constant. Of course there are a few instances when the level was not constant, but I think I may safely say it has not measured as much as 6 inches away from the level we are trying to maintain. With the amount of drift, logs and ice that come down that stream, I think the automatic devices would give a great deal of trouble.

Mr. Blanchard: The flash-boards are of structural steel, sheathed with oak planks and are apparently of the same size as these Tainter gates. The one I speak of had a reinforced concrete counterweight drum rolling up and down on a rack, and it seems to me that by covering over the ends of this drum at the gear wheels, running on the gear-racks, it would be protected from snow and would withstand the ice. I believe that this is the only one used in this country, and not knowing the ice conditions, I was interested to know whether it would be practical in the North. The flash-boards were hinged at the crest of the dam, and cables from their outer corners lead up over pulleys and thence down to the rolling counterweights, so that the additional weight of water on the flash-boards raises the counterweights onto a steeper portion of the rack. The force of gravity, when the load on the flash-board is reduced, will send the counterweight down and raise the flash-board.

Mr. Link: I do not believe a structure of that kind would work satisfactorily in Minnesota, on the Mississippi river, for the reason that many of the logs are dead heads, and some are so long that they drag on the crest of the dam when the lower end strikes the apron, and any structure attached to the crest of the dam would be in danger of being wrecked. The conditions in the North are very bad.

Mr. Gerber: What was the method of placing the explosive beneath those boulders?

a charge under a large boulder and broke it in halves. The pieces were thrown up on top of the ice and the interesting part of it was, that one-half of the boulder fell on one side and the other half on the other side of the channel which had been cut in the ice. It certainly was a neat piece of work, but I suppose it was, in a way, accidental that the boulder should have disposed of itself in that manner. I think the man placed the powder by means of a pipe driven down beside the boulder.

W. W. DeBerard, M. W. S. E.: In regard to the Tainter gates, how much was allowed for deflection? With this long span, can you get a sufficiently straight line at the bottom of the Tainter gate to cause no leakage under pressure?

Mr. Link: The beams used were not figured for deflection, but are so deep in proportion to span that the amount of deflection is small. We depend on the rubber belting for sealing the gate at the bottom instead of the cover plate itself. In cases where the belting is used to form the seal, I think the deflection would have little effect.

H. E. Goldberg, M. W. S. E.: How thick is that rubber belting?

Mr. Link: Six ply on the ends and five ply on the bottom where it is folded.

L. E. Cooley, M. W. S. E.: What is the average discharge on the river?

Mr. Link: The average flow of the stream in the past has been somewhere around, I should say, 20,000 second feet. Perhaps 15,000 second feet would be nearer right. Since 1910 the average flow has been very much below that.

A. S. Coffin: You used a separate oiling system for each machine. Is there any advantage in this?

Mr. Link: It is questionable whether there is any special advantage in the separate oiling systems except in this way—with a central system it must be in duplicate to provide against a breakdown. There was considerable saving in piping in this plant. If we had the central system there would be required probably ten times as much piping as with the unit system.

Mr. Coffin: Is there any advantage in keeping the oil separate for each machine?

Mr. Link: No, there is no particular advantage in keeping the oil separate in each machine. Of course the oil is filtered and it would take just as much filtering capacity for the central system as it takes this way. The same amount of oil would have to be used.

Mr. Cooley: What is your transmission distance?

Mr. Link: The transmission distance is about eleven miles.

E. N. Lake, M. W. S. E.: I would ask the author in regard to his experience with ice and the screens for the forebay and the use of the exposed gantry crane under winter conditions.

Mr. Link: We have not operated the plant through a winter

have one some
practically imp

The No. 1
bay, and when
the forebay, he
experiment pr
plant, it was
No. 1 plant r
racks had to
trouble from
would be dai
breaking the
cause any co

Mr. Lak
would encou

Mr. Li
Mississippi.
down withi
when the w
the ice clog
you will nc
are as bad

Mr. C
mill pond.

Mr. G

Mr. I
Barnes, of
(Wiley, N
liquid wa
ably fami
low the f
lieve, to
F. witho
stant it
somewh
stream i
agitated
form, r
and wh
colder t
growin

M
throug
the w

M
stuffir
The f

flowing into the wheel-pit above the cover.

Mr. Coffin: I was thinking of the first floor.

Mr. Link: The power house floor is 8 or 10 feet above the wheel cover and we have a drain on the wheel cover. If there is any leakage it is caught in a compartment, so to speak, of the wheel cover, and is taken out through the drain. It cannot get up to the powerhouse floor. There is no possibility of that.

Mr. Coffin: I meant through the roof of the scroll case.

Mr. Link: There is no leakage through the roof of the scroll case.

Mr. Warder: What is the relative level of the head water to the generator?

Mr. Link: The head water is 2½ ft. higher than the power house floor, or about 6 inches below the top of the generator foundation.

G. R. Brandon, M. W. S. E.: Are the bearings roller bearings?

Mr. Link: Yes, they are.

Mr. Gerber: I suppose that bearing carries the entire weight.

Mr. Link: Yes, it does. That is, the entire weight of the rotating parts.

Mr. Coffin: Were you able to use your draft tube forms several times?

Mr. Link: Yes. Owing to the way the work had to be carried out, there were four draft tube forms so we had to use three over again. Originally I wanted to build only three, and that would have meant one would have been used three times, but it did not work out that way.

O. F. Dalstrom, M. W. S. E.: Those castings were very unusual, were they not? Were they iron castings?

Mr. Link: The runners were cast iron. The vanes are very thin, the thickest part being not more, perhaps, than 1½ in. They were beautiful castings, in fact, about the finest I have ever seen when size is considered.

Mr. Gerber: Were the blades made and set in the mould and then the rings cast to them afterwards?

Mr. Link: No. Some manufacturers make them in that manner, but they use plate steel for the vanes, press them to the proper form, set them in the mould, and then cast the crown plate and discharge ring.

Mr. Gerber: We sometimes learn through dear experience. I think Mr. Barnes has some illustrations showing how *not* to do things.

W. T. Barnes, M. W. S. E.: In looking over the advance paper some of the photographs reminded me very forcibly of a power house foundation, the construction of which it was my privilege to witness, early in my engineering experience. It was on a section of work adjacent to the section with which I was connected. Al-some views for the benefit of the younger men, illustrating some of the things to look out for, things which Mr. Link was careful to guard against in his excavations, and which were not cared for as well as they might have been in this case.

The power house was for the New Bedford, Mass., water works. The excavation was about 80 ft. square and 16 ft. deep. The method adopted (apparently rather crude) for carrying the bracing from side to side across the excavation was similar in appearance to that adopted in this case. The best tongue and groove sheeting—4 in. Southern Pine— was used, which gave a very tight sheeting around the pit. The method of bracing was to drive round piles on 10 ft. centers in two directions in lines across the pit and then to fit round logs tightly between the adjacent piles as braces, giving a complete checkerboard effect, the same as in the illustrations showing the square timber braces. The braces were tightly fitted to the piles after the piles had been blazed on the four sides, and then, of course, they were tightly braced to the walings; a second set of braces was added as the excavation proceeded, four to five feet lower down, and a third set as they came down. Although the engineer in charge protested against this type of construction, the claim was made that the method had proved successful on other jobs, so its use was allowed in this work. The excavation had been in water-bearing sand, but on approaching the bottom it ran in quick sand and required, I believe, two 8-in. pumps to keep the water down. The sheeting was very tight except at one spot, and there the water flowed in very freely. The contractor had been cautioned about allowing it to continue, but it

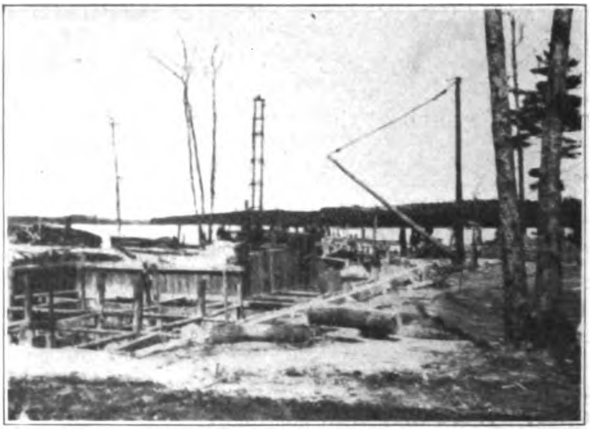


Fig. 21—Showing Bracing

sheeting began to show some cracks, the first 12 ft. away and a second crack a little further away. The appearance of those cracks should have emphasized the necessity of preventing the flow of the water through this one bad place in the sheeting.

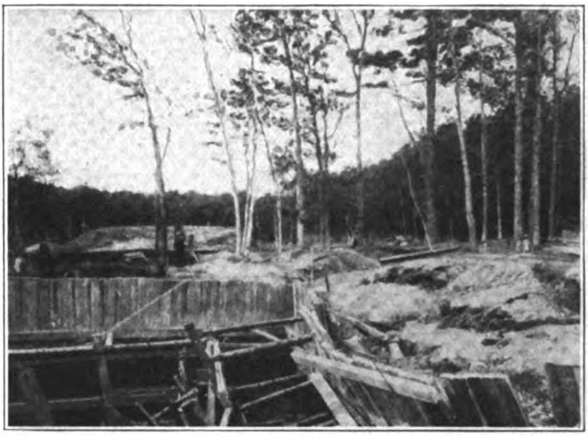


Fig. 22—Showing Cracking of Bank

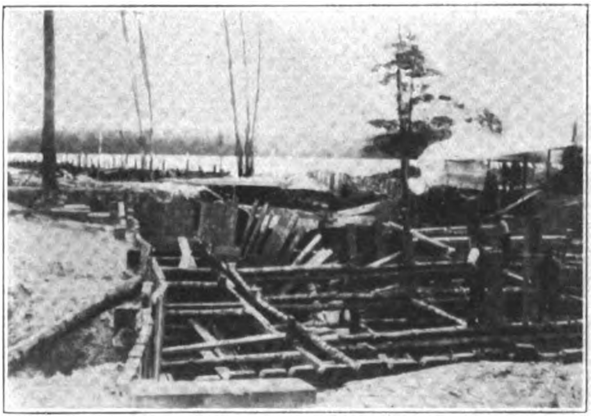


Fig. 23—Showing Location of Pile Thrown Out

The excavation had been carried down to within about 1 ft. of the bottom of the pit, when suddenly one of those round piles, all of which had presumably been driven well below grade, shot into the air, thus loosening the entire system of bracing, and you can imagine the result: The whole thing collapsed, not immediately, but within the next 24 hours.

start, and after two sets of walings were put in, the second driving carried it some distance below grade. As you will see, the sheeting had been driven to place and everything was in very good shape. The braces were practically in a horizontal plane and were, in effect, continuous. The contractor believed he could get the foundation in in good shape with that system, and his reason for using the round timbers was that he could buy them at low cost from the timber men in the vicinity, who made it their business to furnish piles for quite a large territory in New England.

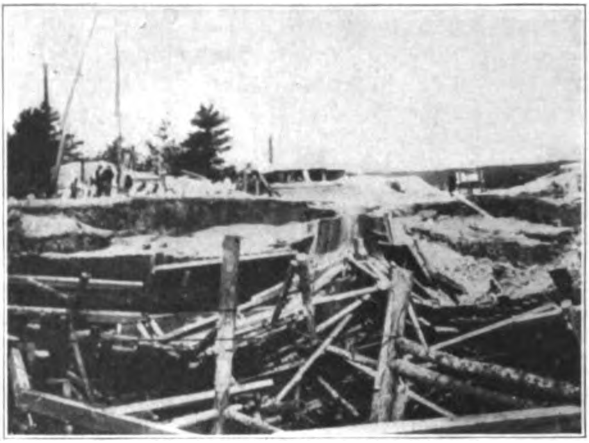


Fig. 24—Condition After Twenty-four Hours

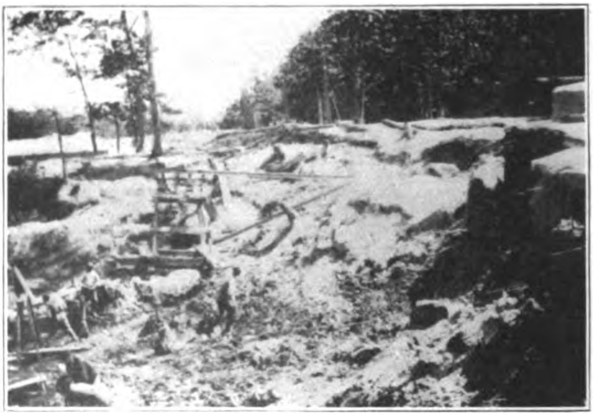


Fig. 25—Progress of Work About Six Weeks After Collapse

Figure 22 is from a photograph taken on the day that the pile about 5 ft. above grade, and the cracks which had developed several days before were merely surface cracks not having caused any settlement, although when the water was caught in a glass you could see that it was really bringing in sand. The contractor was cautioned not to allow it to continue because of the voids that might be produced back of the sheeting.

Figure 23 shows the location of the pile that was thrown out. It was the one 10 ft. beyond this pile that went up, allowing the bracing in four directions to give way.

The following morning it had reached the condition shown in Fig. 24, which, you will see, is hopeless. If I remember right, it took about ten weeks to remove the debris and get to the point where they could get the foundations in place. They made no attempt to replace the sheeting but took out the bank on a slope.

Figure 25 illustrates the work some five or six weeks afterwards, when they were about ready to attempt a portion of the timber grillage; it was a very slow operation, requiring several weeks before they could get the balance in.

Some of the lessons to be drawn from these illustrations are: Look out for water carrying sand in suspension. Watch for cracks in the surface of the soil back of the sheeting. Don't allow the solidity of the cofferdam to be dependent upon the integrity of the entire system of bracing as a single unit.

December, 1914

ING CONGRESS

REPORT OF DELEGATE JAMES B. GIRAND, M. W. S. E.

The American Mining Congress met in its 17th Annual Session in Phoenix, Ariz., December 7th, with a good attendance. An interesting and instructive program had been prepared, and between business meetings notable social events were planned, so there were no dull moments for the delegates.

Addresses, expressing appreciation of the honor conferred on State and City by the meeting of the Congress and extending a hearty welcome to the delegates, were made by Judge Joseph E. Kibby, Judge Richard E. Sloan, Governor G. W. P. Hunt and Mayor Geo. U. Young. These were followed by five minute responses from the leaders of each State delegation. President Wilson's letter of greeting, read by the Secretary, was received with much applause. The President said in part:

> "I am well aware of the important part played by your great organization in the creation of our Bureau of Mines, and am sure that the good work of that bureau in attempting better to safeguard the lives of the 2,000,000 men employed in the hazardous mining and metallurgical industries will continue to redound to your credit, as well as to the credit of the bureau itself. It will always be a tribute to your foresight and energy that this new Federal organization in the short period of its existence, with the kindly co-operation of states and their agencies, has been able by persistent and intelligent effort, to turn an isolated local movement for greater safety into a great national movement for 'safety first' and has already gone beyond the mining industry into every industry of the country. I venture to say that thousands of lives have been saved by that movement and that many thousands more will be saved in the future."

The annual address of President Carl Scholz was scholarly and was received with enthusiasm. He brought out clearly and emphatically some of the great problems that face the mining industry. A brilliant reception to the President and other officers of the Congress followed.

The chief purpose of this session of the American Mining Congress was to endeavor to take the gamble out of mining and put it on a sensible safe basis,—and to this end the questions receiving most discussion were taxation, legislation, and devising means whereby capital could be turned toward the West. On the subject of taxation there were spirited and heated discussions. The principal address on this subject was delivered by the Hon. Thomas E.

presented a report strongly urging the valuation of mining property on the basis of a net annual production. This was firmly opposed by R. C. Allen, State Geologist and Mine Appraiser of Michigan, who upheld the ad valorem system. After much discussion the Congress decided to take no definite action now because it was made plain that conditions vary widely in different states.

Legislation, State and National, was a subject broadly discussed and one by which the Congress hopes to benefit all interests. Conservation was the subject of a splendid address by Dr. William Phillips of Texas, who favored National rather than State conservation. "Conservation," he said, "means Government control over agencies of production, which we have not been able to control, ourselves, to the best advantage. This control to be thoroughly effective must be exercised by the State or the Nation, not both. There may be co-operation in work, but there can be no co-operation in authority."

Strong objections to the provisions of the bill passed by the House of Representatives at the last session of Congress and now before the Senate Committee on Public Lands "to provide for the development of water power and the use of lands in relation thereto," were voiced by E. A. Wedgewood of Salt Lake City in a paper on "Conservation of Western Water Power Resources." "The bill is impracticable from a business standpoint and insufficient assurances of co-operation is given states and private investors by the Federal Government." He ably emphasized the fact that Conservation of Natural Resources demands immediate development of available water powers.

State legislation was under interesting discussion, one of the ablest papers being that of the Honorable Walter Douglas of Bisbee. "The Mine Inspection Law," Mr. Douglas said, "is a positive benefit," while he characterizes the eight-hour law as "pernicious" in that the average wage has been curtailed, and what is more important, the opportunity for advancement. W. G. Swart, of Colorado, declared that most of the laws detrimental to mining are passed because of ignorance. He said, "it is up to us to educate, to let the Legislatures know what we want, and we want nothing more than a square deal."

Wild catters were vigorously scored by Dr. Jas. E. Talmage of Salt Lake City, who urged all mining men to notify the United States postal authorities whenever an offender is found.

Will L. Clark of Jerome, presented the report of the Committee on General Revision of Mining Laws.

On the subject of bringing capital Westward and the protection and promotion of mining interests, Secretary Callbreath's address was full of good sound logic. In part he said, "The West especially needs capital intelligently expended. The owner of a prospect must be given a chance to develop, and the investor must been placed before the public. I suggest a strong organization of mining men in each state, a sort of commission, to which all capitalists will be urged to apply for advice in the matter of placing their money." "Unity is the keynote, inducements must be offered to bring capital and this can be done by seeking legislation just to the investor." The Secretary also recommended State Chapters of the American Mining Congress.

The subject of mining investments and the restoration of public confidence was taken up and the report of the committee read and interesting talks given. Secretary Callbreath read his annual report, showing the financial condition of the Congress.

The Congress conferred its honorary membership this year upon Dr. James Douglas, whose prominence in the mining world is well known.

The election of officers for the ensuing year resulted as follows:

Carl Scholz and J. F. Callbreath were unanimously re-elected respectively President and Secretary for the ensuing year.

OFFICERS OF AMERICAN MINING CONGRESS.

Carl Scholz, Chicago, President.
Harvey Day, Wallace, Idaho, First Vice-President.
M. S. Kemmerer, New York, Second Vice-President.
Geo. H. Dern, Utah, Third Vice-President.
Jos. F. Callbreath, Denver, Secretary.

EXECUTIVE COMMITTEE.

Carl Scholz, Chicago, Ill.
Charles S. Keith.
Walter Douglas, Bisbee, Ariz.

BOARD OF DIRECTORS.

S. A. Taylor, Pittsburg.
Carl Scholz, Chicago.
C. S. Keith.
Walter Douglas, Bisbee.
S. A. Friedman, Nevada.
Faltin Joslin, Alaska.

Place of next meeting not yet determined upon.

Perhaps the most important and far-reaching effort of immediate benefit of the Congress was to pass, without a dissenting vote, the resolution offered by Geo. A. Dern of Utah. The resolution sets forth the condition in the copper mining industry of the West. Half a million people are directly affected by the curtailment of production made necessary by the European war. The National Government was urged to use all possible efforts to open markets for copper and to afford protection to shipments of copper in neutral ships to neutral ports.

MINUTES OF MEETINGS.

Regular Meeting, December 7, 1914.

A regular meeting of the Society (No. 880) was held Monday evening, December 7, 1914. The meeting was called to order at 7:45 p. m. by President Lee with about 180 members and guests in attendance.

The Secretary reported from the Board of Direction, that at their meeting that afternoon applications for admission into the Society had been received from:

Robert M. Dunlap, 2233 Orchard street, Chicago.
Lawrence J. Mortenson, Northwestern University Settlement, Evanston.
Morton Rocha Hunter, 1570 Old Colony building, Chicago.
Jay E. Mason, 1735 Monadnock block, Chicago.
Edwin L. Sinclair, Tama, Iowa.
Franklin Henry Wolever, 724 Oakdale avenue, Chicago.

Also that the following had been elected into the Society:

Eugene Adolph Anderson, 2031 Harrison street, Evanston, Student Member.
Victor H. Bell, Calexico, Cal., Junior Member.
Clarence Sage Roe, 506 So. Capital avenue, Lansing, Mich., Junior Member.
Marion Den Herder Kolyn, 849 N. La Salle street, Chicago, Associate Member.
Horace M. Beebe, 7439 Oakwood boulevard, Chicago, Associate Member.

The Secretary read the following letter from President Greensfelder of the Engineers' Club of St. Louis to President Lee, inviting members of this Society to visit the library and reading rooms at No. 3817 Olive street, St. Louis, and to attend their meetings when it was convenient:

"Mr. E. H. Lee, President,
Western Society of Engineers,
Chicago, Ill.

Dear Mr. Lee:

Several times our attention has been called to the fact that frequently members of your Society visiting St. Louis could be rendered courtesies within the province of our Club. We should like to have you and the members of the Western Society feel that we are at your service at all times. Our Club is open to visitors daily, and at our weekly Wednesday evening meetings we should be glad to welcome engineers who care to avail themselves of these facilities. We should also be pleased to have a member of your Society present a paper before our Club, say sometime in January or February, if such a suggestion meets with your approval.

The few occasions on which our organizations have gotten together proved very enjoyable to us and we trust that the friendly feeling then engendered will continue,

With personal regards, I remain

Yours sincerely,
(Signed) A. P. GREENSFELDER,
President."

Prof. John F. Hayford was then introduced and addressed the meeting on "The Surveys and the Decision in the Costa Rica-Panama Boundary Arbitration." This was an interesting talk illustrated by sundry maps in

O. P. Chamberlain, with replies and explanations by Prof. Hayford and a description of unusual experiences by Mr. Wirt Smith, M.W.S.E., a member of the survey.

The Entertainment Committee also provided some moving pictures which were well received.

The meeting adjourned about 10:10 p. m. and refreshments were served.

Extra Meeting, December 14, 1914.

An extra meeting (No. 881), in the interest of the Bridge and Structural Section, was held Monday evening, December 14, 1914. The meeting was called to order about 8 p. m. by H. C. Lothholz, member of the executive committee, with about 50 members and guests in attendance.

Nominations for members of the executive committee of the Bridge and Structural Section were made as follows:

For Chairman to serve one year,
F. W. Dencer and H. C. Lothholz (one to elect).

For Vice-Chairman to serve one year,
W. S. Lacher.

For members of the executive committee to serve one year,
O. F. Dalstrom, T. L. D. Hadwen and N. M. Stineman (two to elect).

These are to be voted on at the next meeting of the Section, Monday, January 11, 1915.

Dr. Hermann von Schrenk, of St. Louis, was then introduced and read his very interesting paper on "Modern Uses of Wood." A large number of lantern slides were used to illustrate the paper. Discussion followed by W. E. Williams, H. C. Lothholz, F. E. Davidson, Robert S. Lindstrom, Ernest McCullough, E. N. Layfield, H. E. Goldberg, with replies and discussion from Dr. von Schrenk.

At the conclusion Mr. DeBerard, for the Annual Meeting and Dinner Committee, made a statement about the Annual Meeting and Dinner to be held Wednesday, January 13th, 1915, and of the arrangements that are being made for this entertainment.

Meeting adjourned about 10 p. m.

Extra Meeting, December 21, 1914.

An extra meeting of the Society (No. 882) was held Monday evening, December 21, 1914. The meeting was called to order by Mr. G. C. D. Lenth at 7:55 p. m. with about 65 members and guests in attendance. Before taking up the paper for the evening Mr. Tomlinson and Mr. Saner of the committee having in charge the arrangements for the Annual Meeting and Dinner, told of what was planned and what had been done.

The chairman then introduced Mr. William O. Lichtner, M.W.S.E., of Boston, Mass. (associated with Mr. Sanford E. Thompson, Newton Highlands, Mass.), who read their paper on "Construction Management." This was illustrated with a few lantern slides. Discussion followed from Messrs. Lenth, O. P. Chamberlain, Ernest McCullough, J. F. Hayford, F. H. Cenfield, M. R. Hunter, Carl Weber, J. W. Lowell, B. C. Groh, with replies and explanations by Mr. Lichtner. Mr. C. A. Keller contributed to the discussion by a letter which was read by the Secretary.

Meeting adjourned about 10:30 p. m.

J. H. Warder, Secretary.

---

*This paper is not for publication.

AUTOMATIC TELEPHONY. By Arthur Bessey Smith and Wilson Lee Campbell. Cloth; 6 by 9 in.; 397 pages. McGraw-Hill Book Company, New York and London. Price, $4.00.

A résumé of the methods of automatic and semi-automatic telephone operation, circuits, and apparatus. This includes all those systems of telephone exchange equipment in which the operations of completing connections between telephone stations are to a greater or less extent performd by electrically-driven or electrically-controlled mechanical devices, as distinguished from the familiar type of equipment operated manually by expert operators.

No effort has been made to treat the subject from a chronological standpoint, and the principal systems in service at the present time are described and illustrated by very carefully drawn circuit diagrams and detailed descriptions. The principles underlying the various systems are clearly brought out, although in one or two cases the circuits shown are not the latest standard of practice in their particular classification.

The authors frankly state that, owing to the necessity of keeping the subject matter within reasonable limits, "——— the authors have found it impracticable to narrate the full details of the practice of all the manufacturers. They therefore have described fully, typical circuits and apparatus of each of the more important or instructive types on the market, but have found it necessary to confine their discussion of such subjects as traffic, development studies, central office building design, long distance lines equipment, etc., to the practice of some one manufacturer. Wherever this has been found necessary, the practice of the Automatic Electric Company has been followed, and the authors feel that the principles and methods brought out in these chapters are sufficiently applicable to other makes of equipment to supply the wants of students of the general art." On this basis it is easy to understand the apparent undue prominence accorded to the product of the Automatic Electric Company.

The chapter on trunking is very clear and well illustrated and will be found very helpful in acquiring an initial understanding of one of the most marked characteristics of automatic telephone switching, while the chapter on automatic district stations touches upon a development possible only to automatic telephone systems, of the greatest importance from an operating standpoint.

Brief chapters are devoted to the discussion of traffic, development studies, cut-overs, interconnection of exchanges, measured service, and suburban and toll arrangements, while the subscribers' station apparatus and auxiliary equipment for maintenance, testing, and supervision to conform to the practice of the Automatic Electric Company is carefully described.

The volume is a valuable addition to the scant bibliography of the subject and affords a means by which the engineer in general practice may obtain a clear idea of the present trend in telephone engineering, while it will be highly prized by telephone engineers and operating staffs as a book of reference.—J. G. M.

THE REGULATION OF RIVERS. By J. L. Van Ornum, M. Am. Soc. C. E., Professor of Civil Engineering, Washington University, formerly U. S. Assistant Engineer. McGraw-Hill Book Company, New York. 393 pages, 6¼ by 9¼ ins., cloth bound, many illustrations. Price, $4.00.

The relation between transportation on waterways and on railways in past years has been a neglected factor and it has resulted in economic loss and commercial waste.

The provisions of the Mann-Elkins and other acts have now removed ing to the railroads their much-needed increase in freight rates will further tend to promote the public utilization of the cheapest means for transporting those products best suited for the waterway or the railway.

The first chapter of Mr. Van Ornum's book treats upon the commercial considerations of river navigation. The history leading to present conditions is given, together with the reasons why the situation in this country is not normal. The author gives statistics showing that water transportation is essentially cheaper for certain freight. The importance of terminal and transfer facilities is discussed and illustrated by plans of river terminals on the Rhine.

"European experience in waterway transportation has been particularly productive of extensive and splendidly equipped terminals on those channels whose commerce has grown the most rapidly. The Rhine (which carried over 55,000,000 tons in 1912) has more than sixty such interior harbors for the loading, unloading and storage of freight, at about two-thirds of which railway connection and transfer facilities exist."

In this connection the author omitted to mention the present work now being done in the Mississippi Valley to develop publicly-owned terminals at Davenport, Dubuque, Quincy and Kansas City. The chapter closes with a set of valuable diagrams showing the relation between draft and tonnage of river boats with the cost of transportation in mills per ton-mile, which illustrate the reason for the development of the modern type of barges.

Chapter 2 deals with the natural laws relative to river floods, reservoir control, the typical plan and profile of the meander showing the deep pool and erosion at the lands and the bar formation in the crossings.

"Illustrating the limiting effect of the crossings it may be stated that, while there are numerous bars of only 6 or 7 feet natural depth in the 600 miles of the Mississippi River between Cairo and Vicksburg, the average depth at low water between these two cities is 35 feet; while it is twice this below Vicksburg."

A short chapter is given on investigations, surveys, etc., Federal control of navigation and State laws limiting riparian ownership.

Chapter 3 is a comparative review of the five methods employed for the improvement of rivers: 1, by regulation of the stream; 2, by dredging; 3, by canalization; 4, by the construction of a lateral canal; 5, by storage reservoirs. The relative costs and merits of these methods are discussed.

Chapters 5, 6 and 7 take up the principles of regulation, works of channel contraction and the protection of erodible banks, the construction of groynes, mattresses, spur dikes, revetments, and other devices for regulating the current so as to develop more uniform depths of channel and stable regimen.

Chapter 8 is on dredging, the proper location for most effective work, dredging vs. regulation and cost of dredging operations. The average cost of dredging operations on the Lower Mississippi is given as: 18.1c per cubic yard, including operation 8.3c, repair 7.7c and miscellaneous 2.1c.

Under Levees, chapter 9, flood heights and protective measures are discussed. The author is a supporter of the levee system and points out that the tendency of levee systems is to lower the elevation of the bed of the stream.

The work is not a mere compilation. It is a philosophical review of the fundamental principles of stream flow, the agencies effective in stream regulation, together with carefully selected typical examples of methods and structures for such regulation and the results obtainable. Reference is made for authority on all statistics.

The book possesses literary merit and is of interest not only to engineers, but also to the non-technical reader who is interested in the commercial development of river navigation.—L. K. S.

bound. Price, $2.50.

A very interesting book, the result of studies in many parts of the world, first begun nearly twenty years ago on the south coast of England in observation of the shaping of sand drifts by the wind and water. Later these studies of the drifting action of snow under wind action was continued at considerable length in Canada.

Studies of water waves were made by Newton and the theory of their creation was attributed by Dr. Johnson to undulating inequalities. "Periodicity and the transmission of an impulse by the material are the aspects of sea waves which are repeated in the transit of light and sound, and owing to the analogies we speak of waves of light and sound."

The author has made such elaborate study of waves of the atmosphere, hydrosphere and lithosphere, that he calls the subject Kumatology in this book.

Part I considers Aeolian Sand Waves and Aeolian Sand Ripples with illustrations from photographs of their shape, formation, changes, and migration.

In part II consideration is given to snow waves and snow drifts, showing variations of shape, size, similarity to such creations in sands, and yet differing because of the adherence at times of particles of snow, whereas the sand is seldom adherent. These snow studies were mostly carried out in the Canadian Dominion.. One of the curiosities shown from photographs are the snow mushrooms which form on stumps and may be as much as nine feet in diameter with cavities in the snow below them and about the stump roots, caused by action of the wind.

In part III the author takes up the subject of sub-aqueous sand waves, which covers ripple marks and current marks and sand waves in tidal currents. These matters have some application to a study of the bars of our own Mississippi River. The result of these studies the author has applied to a study of watery sands, quick-sands and the ripple clouds which we call a mackerel sky. Much of the author's previous investigations he finds applicable to such celestial phenomena. Taken in all, the book with its many illustrations is full of interest.

THE LIFE AND WORK OF NEWTON (Essays). By Augustus DeMorgan; edited with notes and appendices by Philip E. B. Jourdain. The Open Court Publishing Company, London and Chicago. 5 by 7½ in. Cloth. Price, $1.25.

It is very satisfying, and often the practice, to indulge in a little undeserved hero worship when we review the lives and works of our great philosophers and scientists. In fact, our appreciation of their greatness in practical matters leaves no place in their characters for the natural shortcomings of man.

But this is not Mr. DeMorgan's idea. Instead, he shows us how perfectly human it is for a man to be great. The stand he has taken in the case of Sir Isaac Newton may be gleaned from—"as a man of high principle, no one who knows his history can deny. But when injustice is not merely concealed but openly defended; when meanness is represented as the right of a great philosopher; when oppression is tolerated and its victims are made subjects of obloquy because they did not submit to whatever Newton chose to inflict;—then it becomes the duty of the biographer to bear more hardly upon instances of those feelings than * * * * necessary.

This is one side of Newton that is new to many of us. However great a man he may have been, he was no less a temperamental one. When he had become a ruler among scientists he was dissatisfied because he was not

Especially is this noticeable in the history of his development of fluxions known now as differential calculus. At this time Leibniz was also working on this theory and very openly offered to compare notes with Newton. This Newton very skillfully avoided, to the end that he was given full credit by the Royal Society.

This is but one of the instances which lead us to a closer acquaintance with the real Newton, but none of which detract the least from the greatness of his work. In fact the very instances which Mr. DeMorgan explains so fully and which shatter some of our idealistic conceptions as regard intellectual superiority, really make Newton so human that we cease to think of him as a calculating genius who added so much to our mathematical capacity besides giving us our fundamental laws of gravitation, but rather as one of us who, as Mr. DeMorgan puts it, could intellectually "outdistance us in a foot-race and at the same time carry more than we could lift."

It is a pleasant diversion to read such a biography which tells us of the man rather than chronicles the events of his life which would for the purposes of the book be just as effective inaccurate as accurate.—J. E. M.

AMERICAN SEWERAGE PRACTICE. Vol. I. Design of Sewers by Leonard Metcalf and Harrison P. Eddy, Consulting Engineers, Boston, Mass. McGraw-Hill Book Co., New York and London, 1914. Cloth, 6½x9 inches. Price, $5.00 net.

This book is the first of three volumes on American Sewerage Practice; the second, treating of construction of sewers, being now in the press, and the third, dealing with the design of works for the treatment and disposal of sewage, being still in preparation.

This work was inspired by the lack of definite data on the subject, collected and arranged in such convenient form as to make it readily available in actual design, and also by the lack of uniform and standard practice among the sanitary engineers of the country. It is, therefore, essentially a practical book and is a most valuable addition to the literature on a subject which, owing to its apparent simplicity and the indefinite nature of some of the elements involved, has too often been treated in generalities which have been of little use to the designing engineer.

This book is written by designing and consulting engineers of the highest ability and reputation, and gives to the profession the results of their study and practice presented, not in general terms which leave the designer with little but the knowledge of the size of the task before him, but in a definite and explicit manner in which it is of greatest value. In short, the reviewer believes this volume to be the most complete and usable treatise on practical sewer design yet published.

The volume is divided into seventeen chapters and is replete with tables and diagrams of useful data and illustrations of existing works.

The introduction is an historical sketch of sewerage practice up to the present day and the lessons which have been learned from the experience of the past.

Chapter I discusses the general requirements and the arrangement of sewerage systems and gives examples of existing designs, an interesting and unusual feature being a discussion of the depreciation of sewers.

Chapters II, III and IV treat the hydraulics of sewer design. They discuss the elements involved, give a vast amount of useful and pertinent data, tables, diagrams, and formulae, suggest proper assumptions and standards for the indefinite elements involved in sewer hydraulics, and discuss some opinions of engineering authorities on important subjects where American practice varies.

Chapters V to IX, inclusive, discuss the quantity of sewage to be carried by a proposed system. This most important factor of sewer design is treated are made in many cases where actual records are available.

Chapters X to XIII, inclusive, deal largely with structural details of design and discuss the form, character, and design of various pipes and masonry sewers which are in use. A great many examples of sewer design are shown and one chapter is devoted entirely to the design of masonry arches.

Chapters XIV, XV and XVI are devoted to sewer accessories and give many illustrations of inlets, junctions, and similar structures.

Chapter XVII, "Sewage Pumping Stations," is a general discussion of the subject. It takes up the factors which determine the necessity for such plants and the solution of their size and location. The principal types of pumping machinery are discussed and a number of existing plants are illustrated and explained.

This volume will form a valuable addition to the library of the Sanitary Engineer and it is heartily recommended to those engaged in sewer design.

D. A. G.

December, 1914

The Library Committee desires to return thanks for donations to the library. Since the last publication of the list of such gifts the following publications have been received:

NEW PUBLICATIONS.

McGraw-Hill Book Co.:
- Automatic Telephony, Smith and Campbell. Cloth.
- Graphical Determinations of Sags and Stresses for Overhead Line Construction. Semenza. Cloth.

MISCELLANEOUS GIFTS.

Carnegie Endowment for International Peace:
- Year Book, 1913-14. Cloth.

Chicago Association of Commerce:
- Blue Book of Chicago Commerce; List of Members, Committees, etc. Paper.

Wisconsin Railroad Commission:
- Reports, Vols. 2 to 11. Cloth.

Lyman E. Cooley, M. W. S. E.:
- Report of Commission on Water Power Development of Sanitary District of Chicago. Pam.

Illinois Rivers and Lakes Commission:
- Water Resources of Illinois. Cloth.

Grenville M. Dodge, M. W. S. E.:
- Personal Recollections of President Abraham Lincoln, General Ulysses S. Grant and William T. Sherman. Cloth.

Illinois State Insurance Superintendent:
- Report to Governor on Investigation of Fire Insurance Conditions and Rates in Illinois. Pam.

EXCHANGES.

Canada Department of the Interior:
- Forest Products of Canada, 1913, Pulpwood. Pam.
- Forest Products of Canada, 1913, Poles and Cross-ties. Pam.

Canada Department of Mines:
- Report on the Building and Ornamental Stones of Canada. Paper.
- The Crowsnest Volcanics. Pam.

Canada Commission of Conservation:
- Fifth Annual Report, 1914. Cloth.

Illinois State Geological Survey:
- Bulletin No. 28, Oil and Gas in Bond, Macoupin and Montgomery Counties.

University of Pittsburgh:
- Papers on the Influence of Smoke on Health. Paper.

Iowa Geological Survey:
- Annual Report, 1913. Cloth.

New York State Engineer and Surveyor:
Report, 1913. Parts I and II. Cloth.

American Society of Civil Engineers:
Transactions, December, 1914. Paper.

American Society for Testing Materials:
Proceedings 17th Annual Meeting, 1914, Part I. Paper.

Southwestern Electrical and Gas Association:
Proceedings 9th Annual Convention, 1913. Paper.

Ohio State Board of Health:
Annual Report, 1913. Cloth.

GOVERNMENT PUBLICATIONS.

Steamboat Inspection Service:
General Rules and Regulations Prescribed by the Board of Supervising Engineers. Pam.

U. S. Geological Survey:
Gold, Silver, Copper, Lead and Zinc in Nevada in 1913. Pam.
Gold, Silver, Copper, Lead and Zinc in Idaho and Washington. Pam.
The Production of Natural Gas in 1913. Pam.
The Production of Petroleum in 1913. Pam.
The Stone Industry in the United States in 1913. Pam.
Gold and Silver in 1913. Pam.
The Source, Manufacture and Use of Lime. Pam.
Professional Papers Nos. 90F, 90G.
Bulletins Nos. 541, 561, 562, 580N, 580O, 581C, 581D. Pams.
Water Supply Papers Nos. 326, 329, 340D, 340E, 344, 347. Pams.

U. S. Coast and Geodetic Survey:
Precise Leveling from Brigham, Utah, to San Francisco, Cal.
Annual Report, 1914. Cloth.

U. S. Bureau of Standards:
Technologic Papers Nos. 27-40, incl. Pams.
Bulletin, July, 1914. Paper.

U. S. Bureau of Mines:
Bulletin No. 85, Analysis of Mine and Car Samples of Coals collected in the fiscal years 1911-13. Paper.

U. S. Bureau of the Census:
Taxation and Revenue System of State and Local Governments. Pam.

U. S. Department of Commerce:
Primary Triangulation on the 104th Meridian and on the 39th Parallel in Colorado, Utah and Nevada. Paper.

Secretary of Commerce:
Annual Report, 1914. Pam.

December, 1914

Anderson, Eugene A., Evanston, Ill. Student Member.
Beebe, Horace M., Chicago. Associate Member.
Kolyn, M. D., Chicago. Associate Member.
Roe, Clarence S., Lansing, Mich. Junior Member.

Transfers:

Bell, Victor H., Calexico, Cal., transferred from Student to Junior Member.

Vol. XIX, No. 10

- Abbott, H. R., M.W.S.E. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 608
- Abbott, W. L., M.W.S.E. Discussion of Mr. Salt's paper on Manufacture of By-Product Coke 199
- Aberdeen, S. D., Sewage Disposal Plant at. W. G. Potter 788
- Allen, Andrews, M.W.S.E. The Engineering Opportunities of Our Coal Mining Fields 413
  - Discussion of Prof. Stoek's paper on Mining Laboratories of the University of Illinois 485
  - Discussion of Albert Smith's paper on Wind Loads on Buildings 387-389

- Allen, E. W. Discussion of Mr. Gasche's paper on Power Problems in the Steel Business 498
- Almert, Harold, M.W.S.E. Public Utility Regulation From the Standpoint of the Public and the Engineer 516
- Alvord, John W., M.W.S.E. Discussion of subject "Public Utilities" 528
  - The Future Sanitary Problem of Chicago. A Symposium 757-775
- American Mining Congress, Report of 17th Annual Meeting 1016
- Anderson, Abel O. Memorial 405
- Andrus, Lucius B. Testing of Horizontal Low Head Water Turbines at Elkhart, Indiana 18
- Annual Reports for 1913 86
- Arithmetical Machines. H. E. Goldberg, M.W.S.E. 851
- Armstrong, W. C., M.W.S.E. Discussion of Mr. Pearl's paper on Retaining Walls 139
  - Discussion of Mr. Allen's paper on Engineering Opportunities of Our Coal Mining Fields 439
- Arnold, Bion J., M.W.S.E. City Transportation—Subways and Railroad Terminals 325

- Baker, H. S., M.W.S.E. Discussion of Mr. Greve's paper on Characteristic Curves of Centrifugal Pumps 785
  - Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 594-610
- Baker, I. O., M.W.S.E. Discussion of Mr. Pearl's paper on Retaining Walls 155
- Ball, Dwight B., ASSOC.W.S.E. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 608
- Barnes, W. T., M.W.S.E. Discussion of J. W. Link's paper on Coon Rapids Hydro-Electric Development on the Mississippi River 1011
- Bates, Onward, M.W.S.E. Discussion of subject "Public Utilities" 522
- Bed Rock Under Chicago, Topography of. Roderick Peattie 590
- Bement, A. Discussion of Mr. Salt's paper on the Manufacture of By-Product Coke 200-202
- Boisen, L. N. Discussion of Mr. Young's paper on Outdoor High Tension Substations 223
- Bowen, H. S. M.W.S.E. Discussion of F. William Greve, Jr., paper on Characteristic Curves of Centrifugal Pumps 784, 787
- Boynton, C. W., M.W.S.E. Discussion of Mr. Weber's paper on the Cement Gun and Its Work 309
- Bridge, Reinforced Concrete, at Cedar Rapids, Iowa. Barton J. Sweatt 631
- Bridges, Movable. Wilbur M. Wilson, M.W.S.E. 549
- Brooks, Morgan, M.W.S.E. Discussion of subject "Public Utilities" 539
- By-Product Coke, Manufacture of. T. V. Salt 173

- Campaign to Prevent Fire. Franklin H. Wentworth 258
- Cedar Rapids, Iowa, Reinforced Concrete Bridge at Third Avenue. Barton J. Sweatt 631
- Cement Gun and Its Work. Carl Weber, M.W.S.E. 272
- Centrifugal Pumps, Characteristic Curves of. F. William Greve, Jr. 776
- Chamberlain, O. P. M.W.S.E. Discussion of Mr. Pearl's paper on Retaining Walls 142
- Characteristic Curves of Centrifugal Pumps. F. William Greve, Jr. 776
- Charge for Public Utility Service. M. E. Cooley 1
- City Transportation—Subways and Railroad Terminals. Bion J. Arnold, M.W.S.E. 325

Coke, By-Product, Manufacture of. T. V. Salt.... 173
Comstock, Adam. Memorial.... 317
Concrete, Gravel, Permeability Tests on. Morton O. Withey.... 813
Cone, Albert. Discussion of Mr. North's paper on Grading Yellow Pine Timber for Structural Purposes.... 727
  Discussion of Howard Weiss' paper on the Forest Products Laboratory.... 958
Cooke, Andrew. Public Utilities. Government Regulation of Railroads From the Investor's Standpoint.... 503
Cooley, L. E., M.W.S.E. Discussion of subject "Public Utilities".... 537
Cooley, M. E. Factors Determining a Reasonable Charge for Public Utility Service.... 1
Coon Rapids Low Head Hydro-Electric Development on the Mississippi River Near Minneapolis. J. W. Link.... 979
Corl, W. F. Discussion of Mr. Allen's paper on Engineering Opportunities of Coal Mining Fields.... 449
Cornish, L. D. Panama Canal.... 657
Cravath, J. R., M.W.S.E. Discussion of Mr. Sturm's paper on The Necessity of Ventilation.... 257
Curtis, W. T., M.W.S.E. Discussion of Mr. Allen's paper on Engineering Opportunities of Coal Mining Fields.... 451
Curves, Characteristic, of Centrifugal Pumps. F. William Greve, Jr..... 776

Davidson, F. E., M.W.S.E. Discussion of A. T. North's paper on Grading Yellow Pine Timber for Structural Purposes.... 722
  Discussion of Morton O. Withey's paper on Permeability Tests on Gravel Concrete.... 857
  Discussion of Mr. Wentworth's paper on A Campaign to Prevent Fire....267-271
  Discussion of Mr. Sturm's paper on the Necessity of Ventilation.....245-48-53-55
  Discussion of Mr. Peattie's paper on Bed Rock Under Chicago..600-11
DeBerard, W. W., M.W.S.E. Discussion of W. G. Potter's paper on Sewage Disposal Plant at Aberdeen, S. D....804, 805
DeCrow, C. E. Memorial.... 316
DeWolf, F. W., M.W.S.E. Discussion of Prof. Stoek's paper on the Mining Laboratories of the University of Illinois....483, 485
  Discussion of Mr. Peattie's paper on Bed Rock Under Chicago.... 599
  Discussion of Mr. Salt's paper on the Manufacture of By-Product Coke.... 201
Draper, Robert Strother. Memorial.... 404
Dunn, S. O. Valuation of Public Utilities From the Railway Point of View.... 507

Electrical Inspection. General Discussion.... 612
Electricity, Universal Use of, on the Panama Canal. D. P. Gaillard.... 685
Engineering Opportunities of Our Coal Mining Fields. Andrews Allen, M.W.S.E..... 413
Excursion to Clearing, Midsummer.... 748

Factors Determining a Reasonable Charge for Public Utility Service. M. E. Cooley.... 1
Feustel, Robert M. Some Aspects of the Work of the Illinois Public Utilities Commission.... 965
Finley, W. H., M.W.S.E. Discussion of M. O. Withey's paper on Permeability Tests on Gravel Concrete.... 850
Fire, Campaign to Prevent. Franklin H. Wentworth.... 258
100-Foot Length Standard.... 735
Forest Products Laboratory, Madison, Wis. Howard F. Weiss.... 933
Fox, C. E. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago....604-606
Frame, Three-Legged, Stiff, With Hinged Column Bases. N. M. Stineman, ASSOC.W.S.E..... 881
Future Sanitary Problem of Chicago. A Symposium.... 757

Garcis, John A., M.W.S.E. Discussion of Mr. Allen's paper on The Engineering Opportunities of Our Coal Mining Fields.................... 444
Gasche, F. G. Power Problems in the Steel Business.................. 487
Gansslen, H., ASSOC.W.S.E. Discussion of Mr. Sturm's paper on The Necessity of Ventilation 253
Gear, H. B. Discussion of Mr. Young's paper on Outdoor High Tension Substations 222
Gear, H. B. Discussion of Electrical Inspection................619, 625, 630
Gerber, Emil. Memorial 647
Gerber, W. D., M.W.S.E. Discussion of W. G. Potter's paper on Sewage Disposal Plant at Aberdeen, S. D..............................801-803
Glover, B. H. Discussion of Electrical Inspection...............612, 25, 28
Goldberg, H. E., M.W.S.E. Arithmetical Machines.......................... 859
Government Regulation of Railroads From the Investor's Standpoint. Andrew Cooke 503
Grading Yellow Pine Timber for Structural Purposes. A. T. North.... 706
Grand Stand for the University of Chicago. Charles Hodgdon.......... 72
Grant, B. E., M.W.S.E. Discussion of Mr. Pearl's paper on Retaining Walls 145
Discussion of subject "Public Utilities"........................... 536
Grant, U. S. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 607
Gravel, Concrete, Permeability Tests On. Morton O. Withey.......... 813
Green, F. W., M.W.S.E. Discussion of Mr. Pearl's paper on Retaining Walls 153
Greve, F. William, Jr., ASSOC.W.S.E. Characteristic Curves of Centrifugal Pumps 776
Gun, Cement, and Its Work. Carl Weber.............................. 272

Harza, L. F. Discussion of Mr. Andrus' paper on Testing of Horizontal Low Head Water Turbines at Elkhart, Ind....................... 58
Hatch, J. N. M.W.S.E. Discussion on Engineering Opportunities of Coal Mining Fields 448, 449
Hayford, John F., M.W.S.E. Discussion of Mr. Allen's paper on Engineering Opportunities of Coal Mining Fields....................... 450
Discussion of Mr. Pearl's paper on Retaining Walls.............. 145
High Tension, Outdoor Substations. H. W. Young...................... 204
Hodgdon, Charles. The Grandstand for the University of Chicago.... 72
Holbrook, E. A., and H. H. Stoek. Mining Laboratories of the University of Illinois 459
Horizontal Low Head Water Turbines, Testing. Lucius B. Andrus... 18
Huey, R. S. Discussion of Electrical Inspection.......................624-7
Hydro-Electric Development on the Mississippi River Near Minneapolis. J. W. Link.. 979

Illinois Utilities Commission, Some Aspects of the Work. Robert M. Feustel 965

Jackson, Wm. B., M.W.S.E. Discussion of D. P. Gaillard's paper on Universal Use of Electricity on the Panama Canal...................... 704
Discussion of Mr. Andrus' paper on Testing of Horizontal Low Head Water Turbines 54
Discussion of Mr. Young's paper on Outdoor High Tension Substations 222
Discussion of Mr. Sturm's paper on the Necessity of Ventilation.. 248
Discussion of subject "Public Utilities"........................... 533
Discussion of Mr. Gasche's paper on Power Problems in the Steel Business 495
Johnson, James Whiting. Memorial.................................... 227
Journal, The Making of a Technical. E. J. Mehren.................... 393

King, A. C. Discussion of subject "Public Utilities"................. 538
Kirkpatrick, H. B. Closure of Mr. Salt's paper on the Manufacture of By-Product Coke 202
Kiser, S. E., Alternating Currents 98

Laboratories, Mining of the University of Illinois, H. H. Stoek and E. A. Holbrook 459
Lacher, W. S., Assoc. W.S.E. Discussion of Mr. Pearl's paper on Retaining Walls 148
Lacher, W. S. Discussion of Mr. Sweatt's paper on Reinforced Concrete Bridge at Cedar Rapids, Iowa 643, 644
Lake, E. N., M.W.S.E. Discussion of B. J. Ariold's paper on City Transportation; Subways and Railroad Terminals 355
Lawry, R. G., M.W.S.E. Discussion of Mr. Allen's paper on Engineering Opportunities of Coal Mining Fields 446
Layfield, E. N., M.W.S.E. Discussion of Mr. Sturm's paper on The Necessity of Ventilation 250
Lee, E. H., M.W.S.E. The Future Sanitary Problem of Chicago. A Symposium 757
  Discussion of Morton O. Withey's paper on Permeability Tests on Gravel Concrete 850
  Discussion of Mr. Stoek's paper on Mining Laboratories of the University of Illinois 486
  Discussion of Mr. Allen's paper on The Engineering Opportunities.... of Coal Mining Fields 449
  Address as President-Elect 93
Length, 100-foot Standard of 735
Length, G. C. D., M.W.S.E. Discussion of B. J. Arnold's paper on City Transportation; Subways and Railroad Terminals 357
Libberton, J. H., Assoc. W.S.E. Discussion of Mr. Withey's paper on Permeability Tests on Gravel Concrete 851
Library Notes 109, 231, 322, 410, 547, 655, 754, 810, 930, 1026
Liljencrantz, G. A. M., M.W.S.E. The 100-Foot Length Standard 735
Linderoth, S. Discussion of Mr. Peattie's paper on Bed-Rock Under Chicago 610
Lindstrom, R. S. Discussion of A. T. North's paper on Grading Yellow Pine Timber for Structural Purposes 730
Link, J. W., Coon Rapids Hydro-Electric Development on the Mississippi River near Minneapolis 979
Llewellyn, J. C. Discussion of Mr. Peattie's paper on Bed-Rock Under Chicago 603
Lloyd, Dr. M. G. Discussion of Mr. Young's paper on Outdoor High Tension Sub-stations 225
  Discussion of Mr. Andrus' paper on Testing of Horizontal Low Head Water Turbines at Elkhart, Ind. 57
Lyman, James, M.W.S.E. Discussion of B. J. Arnold's paper on City Transportation; Subways and Railroad Terminals 353

Machines, Arithmetical, H. E. Goldberg, M.W.S.E. 859
Making of a Technical Journal, E. J. Mehren 393
Maltby, A. T., M.W.S.E. Discussion of W. G. Potter's paper on Sewage Disposal Plant at Aberdeen, S. D. 805
Manufacture of By-Product Coke, T. V. Salt, M.W.S.E. 173
Martin, A. J. The Future Sanitary Problem of Chicago. A Symposium 772
McCullough, Ernest, M.W.S.E. Discussion of Mr. Allen's paper on Engineering Opportunities of Coal Mining Fields 443
  Discussion of Mr. Hodgdon's paper on Grand Stand for University of Chicago 81
  Discussion of Mr. Pearl's paper on Retaining Walls 144, 149, 151
McDonnell, J. C. Discussion of Mr. Wentworth's paper on A Campaign to Prevent Fire 268
Mehren, E. J. The Making of a Technical Journal 393
Membership 113, 324, 412, 548, 656, 756, 812, 932, 1028
Memoirs:
  Anderson, Abel O., M.W.S.E. 405
  Comstock, Adam, M.W.S.E. 317
  De Crow, C. E., Aff. W.S.E. 316
  Draper, Robert Strother, M.W.S.E. 404

  Schreiner, Barnabas, M.W.S.E. 921
  Seymour, R. B., M.W.S.E. 649
  Taylor, W. D., M.W.S.E. 650
Midsummer Excursion to Clearing 748
Milton, Taliferro, M.W.S.E. Discussion of Mr. Casche's paper on Power Problems in the Steel Business 496-501
Mining Laboratories of the University of Illinois, H. H. Stoek and E. A. Holbrook 459
Minutes of Meetings 84, 228, 319, 406, 541, 652, 806, 924, 1019
Mississippi River Hydro-Electric Development near Minneapolis. J. W. Link 979
Moderate Capacity Outdoor High Tension Substations, H. W. Young.. 204
Movable Bridges, Types of; W. M. Wilson, M.W.S.E. 549
Musham, J. W., M.W.S.E. Discussion of Mr. Sweatt's paper on Reinforced Concrete Bridge 645

Naylor, C. W., M.W.S.E. Discussion of Electrical Inspection 628
Necessity of Ventilation, Meyer J. Strum 233
Nimmons, G. C. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 600
North, A. T. Discussion of Howard Weiss' paper on the Forest Products Laboratory 956
North, A. T. Grading Yellow Pine Timber for Structural Purposes.... 706

Outdoor High Tension Sub-stations of Moderate Capacity. H. W. Young 204

Panama Canal, A. S. Zinn and L. D. Cornish 657
Panama Canal, Universal Use of Electricity on the, D. P. Gaillard...... 685
Pearl, J. W., M.W.S.E. Retaining Walls 113
  Discussion of Albert Smith's paper on Wind Loads on Buildings 386-390
Pearse, Langdon, M.W.S.E. Discussion of W. G. Potter's paper on Sewage Disposal Plant at Aberdeen, S. D. 802
Permeability Tests on Gravel Concrete, Morton O. Withey 813
Peattie, Roderick. Topography of Bed Rock Under Chicago 590
Perry, L. L. Discussion of Mr. Young's paper on Outdoor High Tension Substations 221
Pine Timber, Yellow, Grading for Structural Purposes, A. T. North.... 706
Plant, Sewage Disposal, at Aberdeen, S. D., W. G. Potter 788
Postel, F. J., M.W.S.E. Discussion of Electrical Inspection 612-629
  Discussion of Mr. Sturm's paper on the Necessity of Ventilation... 256
Potter, W. G., M.W.S.E. Sewage Disposal Plant at Aberdeen, S. D. 788
Power Problems in the Steel Business, F. G. Gasche 487
Pratt, Wm. H. Memorial 922
Public Utilities, Andrew Cooke, Samuel O. Dunn, Harold Almert...... 503
Public Utilities Commission of Illinois, Some Aspects of the Work. Robert M. Feustel 965
Public Utility Regulation from the Standpoint of the Public and the Engineer. Harold Almert 516
Public Utility Service, Factors Determining a Reasonable Charge for. M. E. Cooley 1

Railroad Terminals and Subway; City Transportation. Bion J. Arnold, M.W.S.E. 325
Rasmussen, Frank, M.W.S.E. Discussion of Mr. Allen's paper on Engineering Opportunities in Coal Mining Fields 440
Reactions in a Three-legged Stiff Frame with Hinged Column Bases, N. M. Stineman, Assoc. W.S.E. 881
Reichmann, Albert, M.W.S.E. Address as Retiring President 91
  Discussion of Mr. Allen's paper on Engineering Opportunities in Coal Mining Fields 447
Reinforced Concrete Bridge at Cedar Rapids, Iowa. B. J. Sweatt...... 631
Retaining Walls, J. W. Pearl, M.W.S.E. 113
Richey, J. J. Discussion of N. M. Stineman's paper on Reactions in a Three-legged Stiff Frame with Hinged Column Bases 902

Robinson, W. C., M.W.S.E. Discussion of Mr. Wentworth's paper on A Campaign to Prevent Fire 270
Rock Under Chicago, Topography of. Roderick Peattie........ 590
Roper, D. W., M.W.S.E. Discussion of Mr. Grasche's paper on Power Problems in the Steel Business 494

Sackett, R. L. Discussion of Mr. Andrus' paper on Testing of Horizontal Low Head Water Turbines........ 53
Salt, T. V., M.W.S.E. Manufacture of By-Product Coke........ 173
Saner, C. C., Assoc. W.S.E. Discussion of Mr. Sweatt's paper on Reinforced Concrete Bridge 646
Sanitary Problem of Chicago; The Future. A Symposium........ 757
Scheible, Albert, M.W.S.E. Discussion of Mr. Sturm's paper on the Necessity of Ventilation 249-252
Schreiner, Barnabas. Memorial 921
Schuchardt, R. F., M.W.S.E. Discussion of B. J. Arnold's paper on City Transportation; Subways and R. R. Terminals........347-354
  Discussion of Mr. Young's paper on Outdoor High Tension Substations 220, 222, 226
Sewage Disposal Plant at Aberdeen, S. D. W. G. Potter........ 788
Seymour, R. B. Memorial 649
Shaw, W. A., M.W.S.E. Discussion of subject "Public Utilities"........ 537
Shepherd, J. W. Discussion of Mr. Sturm's paper on the Necessity of Ventilation 245, 251
Sherman, L. K., M.W.S.E. Discussion of W. G. Potter's paper on Sewage Disposal Plant at Aberdeen, S. D........801-803
Smetters, S. T., M.W.S.E. Discussion of A. T. North's paper on Grading Yellow Pine Timber for Structural Purposes........ 727
  Discussion of Mr. Greve's paper on Characteristic Curves of Centrifugal Pumps 785
  Discussion of Mr. Peattie's paper on Bed Rock Under Chicago.. 604-611
Smith, Albert, M.W.S.E. Wind Loads on Buildings........ 369
Smith, Frederick A., M.W.S.E. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 595, 605
Smith, R. C., M.W.S.E. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 601
Smith, T. A. Discussion of N. M. Stineman's paper on Reactions in a Three-legged Stiff Frame with Hinged Column Bases........ 907
Some Aspects of the Work of the Illinois Utilities Commission. Robert M. Feustel 965
Soper, Dr. Geo. A. The Future Sanitary Problem of Chicago. A Symposium 760
Springer, Geo. B., M.W.S.E. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 609
Standard, 100-Foot Length........ 735
Steel Business, Power Problems in the. F. G. Gasche........ 487
Stern, I. F., M.W.S.E. Discussion of Mr. Hodgdon's paper on Grand Stand for the University of Chicago........ 82
  Discussion of Mr. Pearl's paper on Retaining Walls........142-149
  Discussion of Mr. Sweatt's paper on Reinforced Concrete Bridge at Cedar Rapids, Iowa........643-5
Stineman, N. M., Assoc. W.S.E. Reactions in a Three-legged Stiff Frame with Hinged Column Bases 881
Stoek, H. H., M.W.S.E., and E. A. Holbrook, Mining Laboratories of the University of Illinois 459
Structural Purposes, Grading Yellow Pine Timber for. A. T. North... 706
Sturm, Meyer J., M.W.S.E. The Necessity of Ventilation........ 233
Substations, Outdoor High Tension, Moderate Capacity, H. W. Young.. 204
Subways and Railroad Terminals; City Transportation. B. J. Arnold, M.W.S.E. 325
Swanson, S. J. Discussion of Mr. Peattie's paper on Bed Rock Under Chicago 607

Taylor, W. D. Memorial ....
Technical Journal, The Making of. E. J. Mehren ....
Terminals (Railroad) and Subways; City Transportation. Bion J. Arnold, M.W.S.E. ....
Tests, Permeability, on Gravel Concrete, Morton O. Withey............
Testing of Horizontal Low Head Water Turbines. L. B. Andrus......
Third Avenue Reinforced Concrete Bridge at Cedar Rapids, Iowa. Barton J. Sweatt, Assoc. W.S.E. ....
Thorkelson, H. J., M.W.S.E. Discussion of Mr. Sturm's paper on the Necessity of Ventilation ....
Three-legged Stiff Frame with Hinged Column Bases, Reactions in. N. M. Stineman, Assoc. W.S.E. ....
Timber for Structural Purposes, Grading Yellow Pine, A. T. North....
Topography of Bed Rock Under Chicago. Roderick Peattie..........
Tousley, V. H. Discussion of Electrical Inspection..............613,6
Transportation for Chicago; Subways and Railroad Terminals. Bion J. Arnold, M.W.S.E. ....
Tratman, E. E. R., M.W.S.E. Discussion of Mr. Pearl's paper on Retaining Walls ....
  Discussion of Mr. Allen's paper on Engineering Opportunities of Coal Mining Fields ....
Turbines (Water), Testing of Horizontal Low Head. L. B. Andrus..
Types of Movable Bridges. Wilbur M. Wilson, M.W.S.E. ....

Universal Use of Electricity on the Panama Canal. D. P. Gaillard......
University of Chicago's Grand Stand. Charles Hodgdon ....
University of Illinois' Mining Laboratories, H. H. Stoek, M.W.S.E., and E. A. Holbrook ....

Valuation of Public Utilities from the Railway Point of View. Samuel O. Dunn ....
VanEtten, F. C. Discussion of Mr. Young's paper on Outdoor High Tension Substations ....
Vent, Frederick G., M.W.S.E. Discussion of Mr. Allen's paper on Engineering Opportunities of Coal Mining Fields..................448,
  Discussion of B. J. Arnold's paper on City Transportation; Subways and R. R. Terminals 358
  Discussion of Mr. Pearl's paper on Retaining Walls.........149, 150,
Ventilation, Necessity of. Meyer J. Sturm, M.W.S.E..................
Vey, F. E., Assoc. W.S.E. Discussion of N. M. Stineman's paper on Reactions in a Three-Legged Stiff Frame with Hinged Column Bases......

Water Turbines, Testing of Horizontal Low Head at Elkhart, Ind. Lucius B. Andrus....................................
Watson, John D., The Future Sanitary Problem of Chicago. A Symposium ....
Weber, Carl, M.W.S.E. The Cement Gun and Its Work.................
Weiss, Howard F. The Work and Some Accomplishments of the Forest Products Laboratory ....
Wentworth, Franklin H. A Campaign to Prevent Fire.................
West, O. H. Discussion of Mr. Gasche's paper on Power Problems in the Steel Business ....
Wheeler, H. M., M.W.S.E. Discussion of D. P. Gaillard's paper on Universal Use of Electricity on the Panama Canal........................
Wilson, E. B., M.W.S.E. Discussion of Morton O. Withey's paper on Permeability Tests on Gravel Concrete.............................
Wilson, Wilbur M., M.W.S.E. Types of Movable Bridges................
Wind Loads on Bridges. Albert Smith, M.W.S.E.......................
Withey, Morton O. Permeability Tests on Gravel Concrete............
Woodworth, P. B., M.W.S.E. Discussion of Electrical Inspection.........
Work (the) and Some Accomplishments of the Forest Products Laboratory at Madison, Wis. Howard F. Weiss............................

Yellow Pine Timber for Structural Purposes; Grading. A. T. North

BOOK REVIEWS

American Railroad Economics. A. M. Sakolski........ 229
American Sewerage Practice, Vol. I. Leonard Metcalf and Harrison P. Eddy........ 1024
Automatic Telephony. Arthur Bessey Smith and Wilson Lee Campbell. 1021

Chemical Reagents: Their Purity and Tests. Henry Schenck........ 754
Chicago City Manual, 1913. City Statistician........ 753
Compressed Air. Theodore Simons........ 654
Compressed Air Practice. Frank Richards........ 545

Description of Land. R. W. Cantley........ 107
Design of Plate Girders. Lewis E. Moore........ 106
Designing and Detailing of Simple Steel Structures. Clyde T. Morris... 409

Economics of Interurban Railways. Louis E. Fischer........ 320

Foundations of Bridges and Buildings. Henry S. Jacoby........ 654
Freight Terminals and Trains. John A. Droege........ 544
Further Problems in the Theory and Design of Structures. Ewart S. Andrews........ 104

Hand Book of Construction Plant: Its Cost and Efficiency. Richard T. Dana........ 810

Igneous Rocks. Joseph P. Iddings........ 408
Industrial Chemistry for Engineering Students. Henry K. Benson...... 322
Inspection of Concrete Construction. James Cochran........ 408

Liquid Air, Oxygen, Nitrogen. George Claude........ 543

Mechanical Engineer's Reference Book. Henry Harrison Suplee........ 321
Meteorology. Willis Ibister Milham........ 108
Mississippi River Flood Problem, The. John A. Fox........ 751

Observations in Meterology. Rev. Leonard Jenyns........ 108

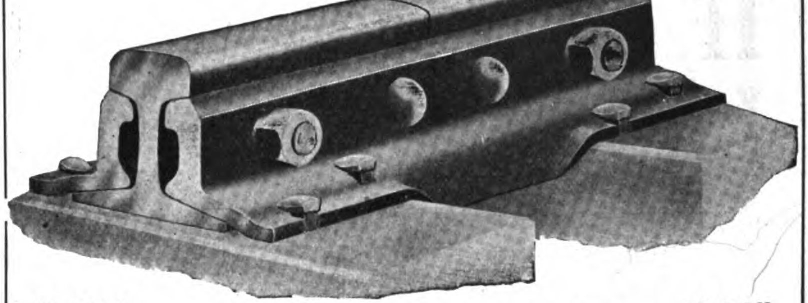
Panama Gateway, The. J. B. Bishop........ 106
Philadelphia Department of Public Works Reports. M. L. Cooke, Director........ 929-930
Power Plant Testing. J. A. Moyer........ 230
Practical Alternating Currents and Alternating Current Testing. Charles F. Smith........ 229

Reader of Scientific and Technical Spanish. Cornelius DeWitt Willcox.. 545
Regulation of Rivers. J. L. Van Ornum........ 1021
Reinforced Concrete Construction, Vol. II. George A. Hool........ 105
Report on Coal in Alaska for Use in United States Navy........ 752

Steel Bridge Designing. Melville B. Wells........ 544
Steel Construction. Henry Jackson Burt........ 928
Strength of Materials. H. E. Murdock........ 927
Structural Engineer's Hand Book. Milo S. Ketchum........ 925
Surveying Manual. Howard Chapin Ives........ 930
Suspension Bridges and Cantilevers: Their Economic Proportions and Limiting Spans. D. B. Stineman........ 229

Technical Mechanics. Edward R. Maurer........ 808
Theory and Design of Structures. Ewart Andrews........ 104
Theory of Arches and Suspension Bridges. J. Melan........ 751
Treatise on General and Industrial Organic Chemistry. Dr. Eltore Molinari........ 809
Treatise of Wooden Trestle Bridges and Their Concrete Substitutes According to the Present Practice of American Railroads. Wolcott C. Foster........ 753

Waves of Sand and Snow and the Eddies that Make Them. Vaughan Cornish........ 1023
Weather and Climate of Chicago. Henry J. Cox........ 808



TRACK Q AND C DEVICES

Q & C BONZANO RAIL JOINT

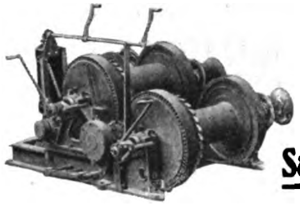
Millions in Use

TRACK Q AND C DEVICES

THE Q & C COMPANY

West Street Bldg.
NEW YORK, N.Y.

Peoples Gas Bldg.
CHICAGO, ILL.



THIS "AMERICAN" ELECTRIC HOIST

represents the maximum of

Safety, Power and Dependability

It can be used for every kind of hoisting—heavy or light, fast or slow.

The ratchet ring is of wrought steel with cut teeth. The load can be locked safely at any point.

Should current suddenly fail the "AMERICAN" Roller Ratchet Brake will absolutely prevent motor backing up and dropping load. This is a feature that never fails.

All parts are made stronger than seems necessary and they are further guarded by a thorough lubrication system.

AMERICAN HOIST & DERRICK COMPANY

ST. PAUL, MINNESOTA

Chicago
New York
Pittsburgh
New Orleans
San Francisco
Los Angeles
Seattle
Portland
Spokane
Denver
Winnipeg
Vancouver
Edmonton
Calgary

If You Are Interested in

Ore dressing and the smelting and refining processes for non-ferrous metals as well as iron or steel;

or,

If you wish to keep in touch with progress in the scientific manufacturing methods in chemical plants and industrial works where engineering chemistry is applied,

YOU SHOULD READ

METALLURGICAL AND CHEMICAL ENGINEERING

It is the only magazine specialized upon the engineering features of the above mentioned industries.

PUBLISHED MONTHLY

Subscription Price - **$2.00 Per Annum, Domestic**
$2.50 Per Annum, Foreign

Ask Us for a Sample Copy Now

Metallurgical and Chemical Engineering

239 West 29th St., NEW YORK

DENVER CHICAGO CLEVELAND PHILADELPHIA LONDON

Consulting and Constructing Engineers

Bridges, and Structures, Coal Tipples, Washeries, Storage and Conveying Plants, Coal Mine Development and Operation, Examinations and Reports

930-936 McCormick Bldg., Chicago

CHICAGO, ILL. **Hartford Bldg**

John W. Alvord
Chas. B. Burdick } **Consulting Engineers**

Water Supply—Sewerage—Water Power

THE ARNOLD COMPANY

ENGINEERS-CONSTRUCTORS
ELECTRICAL — CIVIL — MECHANICAL
105 SOUTH LA SALLE STREET
CHICAGO

BATES & ROGERS CONSTRUCTION CO.

Civil Engineers and Contractors

Telephone Harrison { **7941** / **7942**
585 Old Colony **CHICAGO**

GEORGE W. FULLER
Hydraulic Engineer and Sanitary Expert

Water Supply and Purification, Sewerage and Drainage, Disposal of Sewage and Refuse, Investigations of Epidemics, Water Works Valuations, Supervision of Construction and Operation.

ASSOCIATE: James R. McClintock
170 Broadway, New York City

JAMES O. HEYWORTH

GENERAL CONTRACTOR

Harvester Building **CHICAGO**

Consulting and Supervising Engineers
Inspection of Railway & Structural Materials
Chemical Analyses—Physical Tests
Cement Testing

MONADNOCK BLOCK, CHICAGO
Plymouth Bldg. **Majestic Bldg.**
MINNEAPOLIS **MILWAUKEE**

BION J. ARNOLD

M. A. I. E. E.; M. W. S. E.

CONSULTING ELECTRICAL ENGINEER

Chicago
105 South La Salle St.

New York
154 Nassau St.

BURTON J. ASHLEY
Sanitary Engineer

Sewage Disposal Specialist

Morgan Park Station **CHICAGO**

Telephone Central 888

C. EVERETT CLARK CO.
GENERAL CONTRACTORS AND BUILDERS
Suite 1405-6 Title and Trust Bldg
69 W. Washington St.
CHICAGO, ILL.

JOSEPH HARRINGTON
Advisory Engineer

THE BOILER ROOM
COMBUSTION EFFICIENCY
ORGANIZATION
EQUIPMENT

CONSUMERS BLDG. **CHICAGO, ILL.**

CONCRETE
Reinforced or Plain.
RAILROAD MASONRY
Buildings—Conduits—Reservoirs.
HOEFFER & CO.,
614 Chamber of Commerce Bldg.,
CHICAGO.
A. C. WARREN, Mgr. *Tel. Main 4790*

Illinois Engineering Co.
HEATING ENGINEERS
AUTOMATIC VACUUM SYSTEM
of Steam Heating.
1206-7 MONADNOCK BLOCK, CHICAGO
Telephone 1970 Harrison

T. S. LEAKE & CO.
GENERAL CONTRACTORS
6th Floor, Ellsworth Building
537 South Dearborn St., CHICAGO, ILL.
Telephone Harrison 7682
Railroad Buildings Our Specialty

McMEEN and MILLER
(Incorporated)
Samuel G. McMeen Kempster B. Miller
Leigh S. Keith
ELECTRICAL AND MECHANICAL ENGINEERS
1454 Monadnock Block, Chicago
407 Electric Building, Cleveland

RALPH MODJESKI,
CIVIL ENGINEER.
M. W. S. E., M. Am. Soc. C. E.
750 Orchestra Hall Bldg., Chicago, Ill.
Designing and Construction of Railroad Highway Bridges, Expert Inspection Reports. Masonry Construction, etc.

EARL C. MOSS
M. W. S. E.
CONSULTING AND CONTRACTING ENGINEER
FOR
POWER TRANSMISSION EQUIPMENTS
803 MERCHANTS LOAN AND TRUST BLDG.
CHICAGO
PHONE: CENTRAL 6555

ISHAM RANDOLPH
CONSULTING ENGINEER
1807 COMMERCIAL NATIONAL BANK BUILDING
CHICAGO
MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS
MEMBER WESTERN SOCIETY OF ENGINEERS

FOR ELECTRIC AND
ALLIED PROPERTIES
CHICAGO BOSTON
Harris Trust Bldg. 248 Boylston Street

DABNEY H. MAURY
Mem. Am. Soc. C. E. M. W. S. E. Mem. Am. Soc. M
Consulting Engineer
Water Works, Sewerage,
Power Plants, Appraisals
1137-8 Monadnock Block
CHICAGO

John S. Metcalf Co.
ENGINEERS
The Temple CHICAGO
Designers of
GRAIN ELEVATORS ONLY

PHONE 6868 CENTRAL
MORSE CHAIN COMPANY
Manufacturers of
Silent High Speed Chain
FOR
POWER TRANSMISSION
Earl C. Moss, Mgr. Room 803
Chicago Office 112 W. Adams St.

AMBROSE V. POWELL, C. E.
M. W. S. E. M. AM. SOC. C. E.
DRY DOCKS
HARBOR WORKS
CHAMBER OF COMMERCE BLDG.
CHICAGO

RITTER AND MOTT
CIVIL ENGINEERS
STRUCTURES AND FOUNDATIONS
1707 MARQUETTE BUILDING
CHICAGO

ELECTRICAL ENGINEERS.
Manufacturers of Motors, Dynamos and Special Electrical Machinery
Adams and Loomis Sts., CHICAGO

SAUERMAN BROS.
ENGINEERS AND DEALERS
WIRE ROPE, TRAMWAYS, CABLEWAYS, CABLEWAY EXCAVATORS, POWER SCRAPERS, WIRE ROPE FITTINGS
Monadnock Block CHICAGO

HIRAM J. SLIFER
CONSULTING ENGINEER
925-27, 209 South La Salle Street
CHICAGO, ILL.

C. L. Strobel, Pres't E. Haupt, Sec'y
STROBEL STEEL CONSTRUCTION CO.
Contracting Engineers
Bridges, Steel Structural Work, Lift Bridges, Turntables
1744-48 Monadnock Block...Chicago

ARMOUR INSTITUTE OF TECHNOLOGY
CHICAGO, ILL.
Courses in Electrical, Mechanical, Civil, Chemical, Fire Protection Engineering and Architecture. Completely equipped shops and laboratories. ¶ The Institute Year Book will be sent upon application.

Norwich University
The Military College of the State of Vermont
FOUNDED 1819
COURSES
CIVIL and ELECTRICAL ENGINEERING
Organization and Discipline Strictly Military
H. Spooner, President Northfield, Vermont

SARGENT & LUNDY
ENGINEERS
Room 1412 No. 72 W. Adams St., Chicago

Chicago, Ill. The Rookery
E. C. & R. M. SHANKLAND
CIVIL ENGINEERS
Steel and Reinforced Concrete Building Construction.
Foundations, Examinations and Reports.

CLINTON B. STEWART
Assoc. M. Am. Soc. C. E., Mem. Western Soc. Engrs.
CONSULTING HYDRAULIC ENGINEER
Water Power Water Supply Drainage
303 Wisconsin Bldg., Madison, Wis.

THE RAYMOND W. DULL CO.
Contracting Engineers and Dealers
Sand and Gravel Washing Plants;
Portable Sand and Gravel Tubular Washers;
Drag Line Excavators.
1910-12 Conway Bldg. : : CHICAGO, ILL.

LEWIS INSTITUTE
CHICAGO
Four year course leading to degree of Bachelor of Science in Mechanical Engineering. While the course is planned with special reference to mechanical engineering, much time is devoted to electrical work, and such attention is given to engineering, chemistry, civil engineering and general subjects as to graduate men with broad fundamental training along engineering lines. Catalogue on application.

Rensselaer Polytechnic Institute
ESTABLISHED 1824
SCHOOL of ENGINEERING
CIVIL, MECHANICAL, ELECTRICAL and CHEMICAL ENGINEERING, and GENERAL SCIENCE
Send for a Catalogue. TROY, N.Y.

REFRIGERATING ENGINEER

By-Product Ice Making, Refrigerating and Air Cooling Machinery, Using Exhaust Steam only.

1017 Manhattan Bldg., CHICAGO

Patent Lawyers and Solicitors

PATENTS

United States and Foreign

Corporations Organized
Trade Marks, Copyrights

Suite 1302 Marquette Building
CHICAGO

Streeter Clip and Specialty Co.

Incorporated

MANUFACTURERS OF

STREETER'S STEEL CLIPS

4101-4105 East Ravenswood Park

Telephone Graceland 1658 CHICAGO

HIGH GRADE WELDED CHAINS of all descriptions. Steam Shovel Chains a specialty.

S. G. Taylor Chain Co.

642 Marquette Bldg. Chicago, Ill.

DOLESE & SHEPARD CO.

Producers and Shippers of

Crushed Stone for Concrete, Flux and Road Work.

R. R. Ballast (all sizes).

Crushed Limestone surpasses all other materials for R. R. Ballast.

Does not rot ties. Does not eat out bearings. Is free from dust.

All up-to-date Railroads use Stone Ballast.

Phone, Main 378 **108 S. La Salle Street., CHICAGO**

THE WORLD'S FINEST LINE OF

MEASURING TAPES AND RULES

In the highest degree ACCURATE, DEPENDABLE, DURABLE

A complete line—25 years experience in the manufacture of goods of this kind.

ALL THIS **LUFKIN** STANDS FOR

SEND FOR CATALOG THE LUFKIN RULE CO. SAGINAW, MICH.
New York London, Eng.
Windsor, Can.

For Sale—By the Secretary

Books—Smithsonian Institution, Washington. Annual reports for 1896 to 1908, inclusive, except 1904. 12 Vols. cloth bound.

American Society of Mechanical Engineers. Transactions for 1894-5-6-8 and 1905. 5 Vols. in stiff paper covers.

RAILROAD MACHINERY

TRANSFER TABLES,
TURNTABLE SWINGING ATTACHMENTS,
DRAWBRIDGE MACHINERY,
TRAVELLING CRANES.

Old Colony CHICAGO

EUGENE DIETZGEN CO.

LEADING INSTRUMENT MANUFACTURERS

166 W. MONROE ST., CHICAGO

NEW YORK SAN FRANCISCO NEW ORLEANS TORONTO

WISCONSIN BRIDGE & IRON COMPANY

MILWAUKEE, WIS.

THE MONTHLY OFFICIAL RAILWAY LIST

THE MONTHLY OFFICIAL RAILWAY LIST

is the oldest, largest, most complete, and by far the most widely circulated publication of its kind in the world.

A Complete Directory of the Steam Railways of North America and their Officials and Sub-Officials

Also a List of Fast Freight and Private Car Lines and their officials, and much other information useful to railway men, manufacturers, etc.

THE MONTHLY OFFICIAL RAILWAY LIST

431 S. DEARBORN STREET, CHICAGO

Manufacturers and dealers should buy their advertising as they do other material, by comparing prices and quality. Compare the "THIRTY DAY" List with any other similar publication as regards accuracy and completeness.

Green Chain Grate Stokers

***FOR* Water Tube and Tubular Boilers**

Green Engineering Co.

Main Offices

28 East Jackson Street, Chicago

PATENTED GECO APPLIANCES

Catalogue "G"—Green Chain Grate Stokers for Free Burning Bituminous Coals.

Catalogue "L"—"L" type Green Chain Grate Stokers for Coking Coals.

Catalogue No. 8—GECO Pneumatic Ash Handling Systems.

SENT ON APPLICATION

CENTRAL STATION SERVICE

ELECTRIC HEAT LIGHT POWER

Economical Generation of Electric Power

When in need of Electrical Supplies of any kind call Randolph 1280

is possible only with large units and a well organized operating force. Why maintain an expensive plant when you can realize the profit of Commonwealth Edison economies?

Commonwealth Edison Company

120 West Adams Street **CHICAGO**

100-A

Scale and Economy Cannot Exist in Same Boiler Plant

ENTER SCALE—EXIT ECONOMY

As soon as scale forms on the heating surfaces, efficiency decreases, and coal bills increase. In fact, you can get as much work out of a small boiler that is clean as you can out of a large boiler with scale filled tubes.

Economy means continually clean boilers—and this can be accomplished only by **continuous treatment** of the water with proper **reagents. This is the Dearborn Method.**

DEARBORN CHEMICAL COMPANY, McCormick Building, Chicago

CALDWELL

ELEVATING, CONVEYING AND POWER-TRANSMITTING MACHINERY

Labor Saving Devices for Mechanically Handling Raw or Finished Material in Packages or Bulk

H. W. CALDWELL & SON CO.

17th Street and Western Avenue, - CHICAGO

SARCO No. 6 WATERPROOFING

Used where a permanent and absolutely waterproof material is 'demanded. Successfully withstands severest conditions.

SARCO MINERAL RUBBER FLOORS

The most economical, durable, elastic, sanitary, dustless and noiseless floor laid. Satisfactorily used where all other floors fail.

SARCO MINERAL RUBBER PIPE DIP

A permanent, tasteless, odorless insulation. Perfectly protects against acids, alkalies and electrolytic conditions.

Booklets 108E, 112F, 107G on above subjects free for the asking.

SARCO **STANDARD ASPHALT & RUBBER CO.** SARCO

137 So. La Salle Street, Chicago

CHICAGO AA CEMENT

Made in one mill and from one quarry only, "CHICAGO AA" Portland Cement is always uniform in quality. When you use this brand, regardless of place of purchase, you can easily forecast results. "CHICAGO AA" has made good in service—it has stood the test of time.

"The Best That Can be Made"

Chicago Portland Cement Co.
30 N. La Salle St. Chicago

LUPTON

PRODUCTS SERVICE

For maximum light, ventilation and durability specify Lupton Steel Sash

Send for Catalog No. 7

DAVID LUPTON'S SONS COMPANY

Factory, Philadelphia, Pa. **921 Peoples Gas Building, Chicago**

University of Illinois

Edmund J. James, President

This University Comprises the Following:

College of Literature and Arts
Colleges of Medicine and Dentistry
College of Science
College of Law
Graduate School
Agricultural Experiment Station
School of Music
College of Engineering
College of Agriculture
School of Library Science
School of Pharmacy
Engineering Experiment Station

The College of Engineering Offers the Following Four-Year Professional Courses:

1. Architecture
2. Architectural Engineering
3. Civil Engineering
4. Electrical Engineering
5. Mechanical Engineering
6. Mining Engineering
7. Railway Civil Engineering
8. Railway Electrical Engineering
9. Railway Mechanical Engineering
10. Municipal and Sanitary Engineering

For Information, Catalogs, Special Circular, Etc., Address:

Registrar, URBANA, ILL.

IN LENGTHS REQUIRED
READY FOR IMMEDIATE SHIPMENT FROM

WAREHOUSE DEPT., ILLINOIS STEEL CO.

1319 Wabansia Avenue, CHICAGO, ILL.

P. O. Box I. I. -:- Telephone, Monroe 6484

Beams
H-Beams
Channels
Angles
Tees
Zees
Sheared Plates
Universal Mill Plates
} Open Hearth Railway Bridge Quality.

Checkered Plates
Screen Bars
Blue Annealed Sheets
Black Sheets
Bands.
Polished Shafting.
Screw Stock, Cold Drawn
Rails
Rail Splice Bars
Track Bolts
Track Spikes
Machine Bolts
Sheet Piling
} Standard Quality

Rounds { Open Hearth Railway Bridge Quality..
" " Forging and Welding Quality
Shafting Quality.

Squares
Flats
{ Open Hearth Railway Bridge Quality
" " Forging and Welding Quality.

Electric Nickel Steel.

Cold Twisted Squares, Open Hearth Railway Bridge Quality.

Billets, Open Hearth Forging Quality.

Rivet Rods { Open Hearth Structural Quality.
" " Boiler Quality.

Button Head Rivets
Countersunk Head Rivets
Button Head Draw Bar Rivets
} Open Hearth Structural Quality

Cone Head Rivets, Open Hearth Boiler Quality.

Our stock list showing sizes and quantities of material on hand will be sent promptly on application.

American Bridge Company

ENGINEERS
MANUFACTURERS and CONTRACTORS
FOR

STEEL BRIDGES
STEEL BUILDINGS

AND ALL CLASSES OF

METALLIC STRUCTURES

Branch Offices and Works:

Atlanta, Ga.
Boston, Mass.
Buffalo, N. Y.
Baltimore, Md.
Brooklyn, N. Y.
Canton, Ohio
Cleveland, Ohio
Denver, Colo.
Elmira, N. Y.
Kansas City
Toledo, Ohio
Milwaukee, Wis
Minneapolis, Minn.
New Orleans, La.
Pencoyd, Pa.
Philadelphia, Pa.
Pittsburg, Pa.
Richmond, Va.
Seattle, Wash.
San Francisco, Cal.
Salt Lake City, Utah
Trenton, N. J.
Edgemoor, Del.
Youngstown, Ohio

We have decided to carry at all our plants, a large stock of raw material from which we can furnish with great prompiness any ordinary orders for

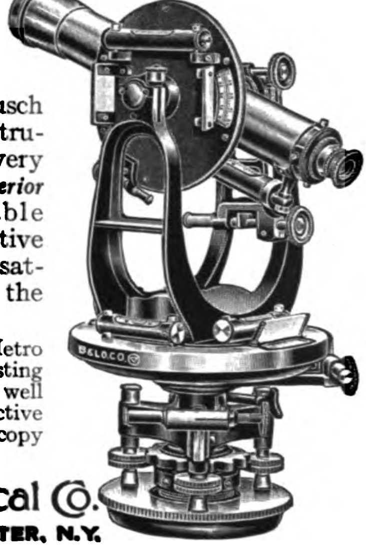
Steel Bridges, Roofs
Buildings
Columns, Girders
Beams, Channels
Angles, Plates, etc.

Western Plants

DETROIT BRANCH
LASSIG BRANCH
AMERICAN BRANCH
MINNEAPOLIS BRANCH
GARY BRANCH

AUGUST ZIESING
PRESIDENT
COMMERCIAL NATIONAL BANK BLDG.
CHICAGO

Focusing



AN exclusive feature of the Bausch & Lomb Engineering Instruments that should appeal to every progressive engineer is the *interior system of focusing.* The movable negative lens between the objective and the diaphragm is the most satisfactory method of solving the focusing problem.

Our new Catalog Metro III gives an interesting discussion of this, as well many other distinctive features. Write for a copy *today*.

Bausch & Lomb Optical Co.

703 ST. PAUL STREET ROCHESTER, N.Y.

NEW YORK, 200 Fifth Ave. WASHINGTON, 613-15th St., N. W.
CHICAGO, 122 S. Michigan Blvd. SAN FRANCISCO, 154 Sutter St.

Theodolite No. 606

H. A. BISHOP

GENERAL CONTRACTOR

BUILDING CONSTRUCTION **FIRE BRICK CONSTRUCTION**

431-3 Commercial Nat'l Bank Bldg., Chicago.

Telephone Randolph, 2684

On the Sag Canal

SULLIVAN CHANNELERS

have again shown their superior speed and economy in cutting rock walls, as they did on the main canal in 1893-4. Catalog 2168-A.

Sullivan Machinery Co.

122 South Michigan Ave., Chicago

Reinforced Concrete Water Tower Waterproofed With

CERESIT
TRADE MARK

The Dependable Waterproofer for Cement

This tower constructed by the Graham Campion Co., Contractors, of Philadelphia, has a capacity of 10,000 gallons.

The use of Ceresit has made it perfectly watertight. Ceresit has been successfully used in hundreds of instances for waterproofing engineering constructions under hydrostatic pressure—such as water towers and tanks, sewers, dams, swimming pools, fountains, conduits, etc.

It is equally effective in waterproofing against dampness, ground water or rain, as in basements, sub-basements, tunnels, walls, floors, roofs, etc.

Every Engineer should have a copy of the Ceresit "Book of Evidence." Sent free—write for it.

Ceresit Waterproofing Company

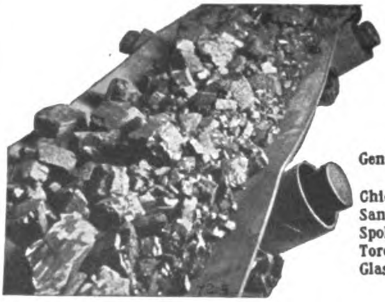
932 Westminster Bldg., Chicago, Ill.

Triangle Mesh
Concrete
Reinforcement
Made by
American Steel & Wire Co.
CHICAGO, NEW YORK, DENVER, SAN FRANCISCO.

ROBINS BELT CONVEYOR

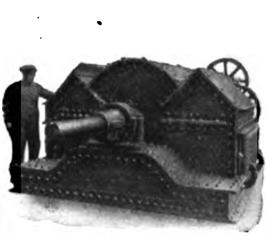
The Robins Belt Conveyor was the original and is today the standard of this type of conveying machinery. Conveying, Elevating and Hoisting Machinery. Robins Coal and Coke Crushers. We carry a complete stock of chains and sprockets.

Write for Monthly Bulletins.

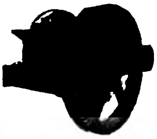


ROBINS CONVEYING BELT CO.
General Office, 13 Park Row, New York
Chicago - - - Old Colony Building
San Francisco - The Griffin Company
Spokane - - - United Iron Works
Toronto: Gutta Percha & Rubber Mfg. Co.
Glasgow, N. S.: Brown Machine Co., Ltd.

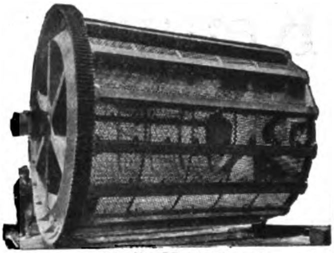
PENNSYLVANIA
Coal Crushers & Cleaners



Hammer Crusher
[PATENTED]



Single Roll
Crusher



BradfordCoal Cleaner
[PATENTED]

Coal Crushing and Cleaning Machinery for By-Product and Bee-Hive Coke Plants, Coal Mines and Power Houses.

Crushers & Cleaners for Iron Ores. Delamater Sink & Float Coal Tester.

PENNSYLVANIA CRUSHER CO.

NEW YORK
50 Church St.

Stephen Girard Bldg.
PHILADELPHIA

PITTSBURGH
Machesney Bldg.

Hercules Steel
Bumping Posts

are the *Best* and *Strongest.*
For full information and catalogue, write

Railway & Traction Supply Co.
Sole Manufacturers
1307 Rector Bldg., CHICAGO, ILL.

Long Distance Telephone Randolph 1488.

Kenwood Bridge Co.

Engineers and Builders
OF
Structural Steel Work

Office, First National Bank Building, Chicago
Works, Grand Crossing, Ill.

Steel Roofs, Bridges, Columns, Girders, Etc.
Made from our Chicago stock for prompt deliveries

DESIGNS AND ESTIMATES FURNISHED ON APPLICATION

Telephone Central 55

MORAVA CONSTRUCTION CO.

ENGINEERS AND CONTRACTORS,
1043 Peoples Gas Bldg.
STRUCTURAL STEEL AND BRIDGE WORKS,
85th St. and Stewart Ave., Chicago

Crushers, Grinders or Shredder
Write "WILLIAMS"

We issue the following catalogs:

Coal Crusher Catalog—For all those crushing and grinding coal, etc

Cement and Limestone Catalog { Limestone, Gypsum and Similar Grinders.

Fertilizer Catalog—Bone, Tankage, Shells and Fertilizer Work.

Clay Catalog—Clay, Shale, etc., for Brick, Tile and Terra Cotta

Oil Cake Catalog { Linseed, Cottonseed and Similar Oil Cake Grinders

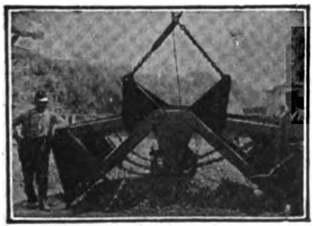
Shredder Catalog—Bark, Chips, Cork and all Fibrous Material

Stock Food Catalog—All Cereals for Feed Millers, Alfalfa, et

Which catalog are you interested in?

We Crush, Grind and Shred Hundreds of Materials.

THE WILLIAMS PATENT CRUSHER AND PULVERIZER CO
Old Colony Building, Chicago, Ill. Works, St. Louis, Mo



Note the Wide Opening 50% Greater Than Clam Shells.

The Best and Most Powerf

GRAB BUCKE

for Excavating and Rehandli Bulk Material

are manufactured by

ANDRESEN-EVANS C

635 Railway Exchange Bldg. CHICA

BOOKS FOR SAL

IRON AGE— Vols. 72, 1903, to 86, 1910. 15 Vols.
ENGINEERING NEWS—Vols. 49, 1903, to 58, 1907. 10 Vols.

All in Choice Half Leather, Library Binding. Price on application

The Secretary W. S. E. 1735 Monadnock Blk. **Chica**

General Office and Factories, HOBOKEN, N. J.

NEW YORK: 127 Fulton St.
CHICAGO: 516 S. Dearborn St.
ST. LOUIS: 813 Locust St.
SAN FRANCISCO 48-50 Second St.

Drawing Materials, Surveying Instruments,
Measuring Tapes, Drawing and Blue Print
Papers, T-Squares, Triangles, Scales, etc.

Repairing of instruments promptly executed. 550 page catalogue on application.

H. M. Byllesby & Company
ENGINEERS—MANAGERS

Design	Construct	Operate
Electric Light Plants	Water Power Plants	Irrigation Systems
Street Railways	Transmission Systems	Water Works
Interurban Railways	Artificial Gas Systems	Drainage Systems
	Natural Gas Systems	

Engineering, Commercial and Legal Examinations and Reports
CONTINENTAL AND COMMERCIAL BANK BUILDING,
CHICAGO
New York Tacoma, Wash.

For all Exposed Metal Surfaces

"Superior Graphite Paint"

affords the most thorough protection. Made in six colors. For particulars address

DETROIT GRAPHITE COMPANY
PAINT MAKERS
CHICAGO DETROIT NEW YORK

FIDELITY AND DEPOSIT CO. OF MARYLAND
CONTRACT BONDS for Contractors Guaranteeing the Completion of Contracts
LONDON GUARANTEE & ACCIDENT CO., Ltd.
OF LONDON, ENGLAND

Workmen's Compensation and Employer's Liability Insurance.
Owner's Liability, Burglary, Accident and Steam Boiler Insurance.

CONKLING, PRICE & WEBB
GENERAL AGENTS

INSURANCE EXCHANGE
175 W. JACKSON BLVD.
Telephone Wabash 1280
CHICAGO, ILL.

Bayley

Manufacturing Co.
Milwaukee, Wis.

Heating and Ventilating Engineers

Manufacturers **Contractors** **Specialists in R.R. Building Heating and Ventilating**

Fans—Blowers—Engines *YOUR INQUIRIES SOLICITED*

F. D. CROFOOT

PRINTING BY ELECTRIC LIGHT

Crofoot, Nielson & Company

BLUE PRINTERS

Blue Printing, Black Printing **Blue Line and Color Printing**

Special Service Always—Speed and RESULTS. Big Floor Space and Equipment for Rush Orders.

180 W. Washington Street, CHICAGO
Phone 759 Main

ROBERT W. HUNT & CO.
ENGINEERS

Bureau of Inspection, Tests and Consultation

Consulting, Designing and Supervising Engineers.
Inspectors of Railroad and Structural Materials and Equipment.
Chemical and Physical Tests of all Materials.

CHICAGO NEW YORK PITTSBURG ST. LOUIS
SAN FRANCISCO LONDON MONTREAL
TORONTO MEXICO CITY SEATTLE

HYDRAULIC TOOLS

W-S HYDRAULIC
TRADE-MARK

Pumps, Accumulators, Presses, Punches, Shears, Shafts, Straighteners, Bolt Forcers, Rail Benders, Jacks, Valves, Fittings, Etc. We build to order to meet special requirements.

Write for Catalogs

1585 Hudson Term. Bldg., NEW YORK **THE WATSON-STILLMAN CO.** Room 1547 332 S. Michigan Av. CHICAGO

Announcement of Prizes..Inside front cover
Alvord & Burdick....................IV
Allen & Garcia Co....................IV
American Bridge Co.................XIII
Am. Bureau of Inspection & Tests....IV
American Hoist & Derrick Co..........I
American Steel & Wire Co..........XVI
Andresen-Evans Co..................XIX
Armour Institute Technology..........VI
Arnold, Bion J.......................IV
Arnold Co., The......................IV
Ashley, Burton J.....................IV

Bates & Rogers Construction Co......IV
Bausch & Lomb Optical Co...........XIV
Bayley Manufacturing Co...........XXI
Bishop, H. A.......................XIV
Byllesby, H. M., & Co...............XX

Caldwell, H. W., & Son...............X
Carbondale Machine Co..............VII
Ceresit Waterproofing Co............XV
Chicago Bridge & Iron Works......XXIV
Chicago Portland Cement Co.........XI
Chicago Telephone Co...Inside back cover
Clark Co., C. Everett................IV
Clark, Myron C., Publishing Co...........................Inside back cover
Commonwealth Edison Co.............IX
Conkling, Price & Webb..............XX
Crofoot, Nielson & Co...............XXI

Dearborn Chemical Works..............X
Detroit Graphite Co..................XX
Dietzgen Co., Eugene...............VIII
Dolese & Shepard Co...............VII
Dull, Raymond W., Co................VI

Engineering Books, W. S. E..........XIX

Fuller, Geo. W.......................IV

Great Lakes D. & D. Co.............III
Green Engineering Co.................IX

Harrington, Joseph...................IV
Heyworth, James O....................IV
Hoeffer & Co.........................IV
Hunt & Co., Robert W...............XXI

Illinois Engineering Co................V
Illinois Steel Co....................XII

Jackson, D. C. & W. B................V

Keuffel & Esser Co...................XX
Kenwood Bridge Co...............XVIII

Leake, T. S. & Co....................V
Lewis Institute, Chicago.............VI
Lidgerwood Mfg. Co....Inside back cover
Lufkin Rule Co......................VII
Lupton's, David, Sons Co............XI

Maury, Dabney H.....................V
Metallurgical and Chemical Eng........II
Metcalf Co., John S..................V
McCormick Waterproofing.Back page cover
McMeen & Miller.....................V
Modjeski, Ralph......................V
Monthly Official Railway List.......VIII
Morava Construction Co...........XVIII
Morse Chain Co.......................V
Moss, Earl C..........................V

Nichols, Geo. P. & Bro.............VIII
Norwich University VI

Pennsylvania Crusher Co..........XVII
Poole & Cromer.....................VII
Powell, A. V..........................V

Q. & C. Co............................I

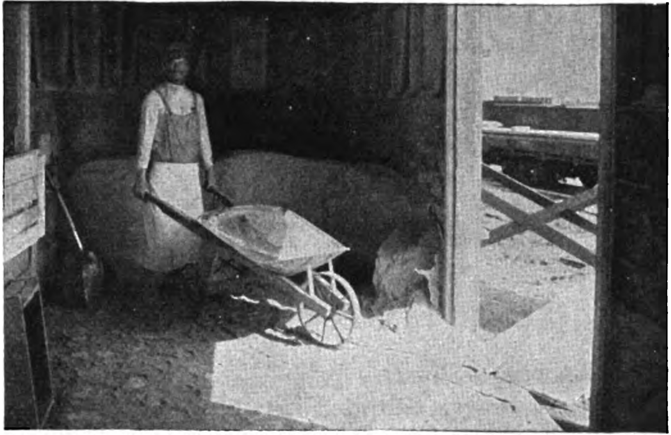
Railway & Traction Supply Co......XVII
Randolph, Isham......................V
Rensselaer Polytechnic Institute.......VI
Ritter & Mott.........................V
Robins Belt Conveying Co...........XVI
Roth Bros. & Co.....................VI

Sargent & Lundy.....................VI
Sauerman Bros. VI
Shankland, E. C. & R. M.............VI
Slifer, Hiram J.......................VI
Snow, T. W., Construction Co.......................Back page cover
Standard Asphalt & Rubber Co.........X
Stewart, Clinton B...................VI
Streator Clip & Specialty Co..........VII
Strobel Steel Construction Co.........VI
Sullivan Machinery Co..............XIV

Taylor, S. G. & Co..................VII

Universal Portland Cement Co......XXIII
University of Illinois..................XI

Watson-Stillman Co.................XXI
Williams Crusher Co.................XIX
Wisconsin Bridge & Iron Co.........VIII



Cement in Bulk eliminates all sack troubles

Cement In Bulk

May be used on many jobs. Are you sure you can't save money by receiving your cement shipments in bulk?

Many engineers and contractors have found that the use of bulk cement results in many economies. It saves the services of one, two or more men and greatly reduces sack troubles and losses.

Write for our Booklet "The Economy of Bulk Cement."

UNIVERSAL
PORTLAND CEMENT CO.

—OFFICES—

Chicago : 208 South La Salle Street
Pittsburgh :: :: :: Frick Bldg.
Minneapolis : Security Bank Bldg.

Plants at Chicago and Pittsburgh
Annual Output 12,000,000 Barrels

STEEL TANKS

Low Cost, Permanent Structures
No Frost Proofing Necessary

Chicago Bridge
and Iron Works

Engineers and Contractors for
Water Towers, Stand Pipes, Smokestacks,
Grain Tanks, Riveted Pipe, Roof Trusses,
Buildings, Bridges, Locomotive Turntables.

105th and Throop Sts. CHICAGO

Reprints

Suppression of Industrial Smoke, etc.
also
The Testing of Coal
A. BEMENT, M. W. S. E.——From Journal, December, 1906
160 page Pamphlet, in Cover. Price 25c.

The Present Status of the Producer-Gas Power Plant in the United States
R. H FERNALD, U. S. Fuel Testing Plant at St. Louis, Mo.
From Journal, October, 1907
60 page Pamphlet, Illustrations and Tables. Price 25c.

The Opportunities in the Electrical Business and General Discussion
GEORGE A. DAMON, M. W. S. E., and many others
50 page Pamphlet in Cover. Price 10c.

A limited number of the above are for sale by the Secretary—W. S. E.

6

Engineering and Contracting
for a month, without charge, to any member of the Western Society of Engineers who would like to examine the publication with a view to subscribing. We will also send, on request, a descriptive catalogue of **BOOKS** on Civil Engineering subjects which we publish.

The Myron C. Clark Publishing Co.
608 S. Dearborn St., Chicago

Lidgerwood

Hoisting Engines
Electric Hoists
Cableways
Logskidding Engines

LIDGERWOOD-CRAWFORD EXCAVATOR

LIDGERWOOD RAPID UNLOADER
ORANGE PEEL AND CLAM SHELL BUCKETS

LIDGERWOOD MANUFACTURING COMPANY
1917 Fisher Building, CHICAGO

Bell System

Removals from one location to another break many friendly ties.

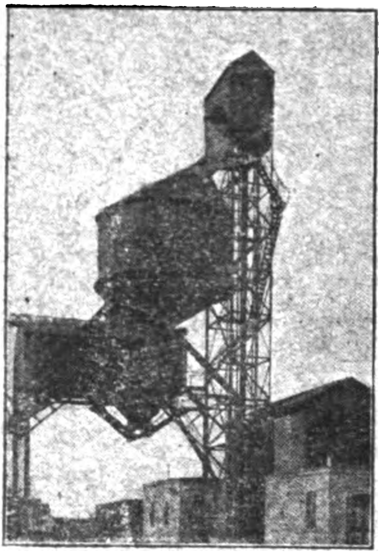
Friendships grow cold through absence.

The Long Distance Telephone is not affected by location nor time. It is always ready. It is the real conserver of friendship.

Chicago Telephone Company
Bell Telephone Building
Official 100

WATER PROOFING NEW YORK BOSTON FT. WORTH

Used for Waterproofing the LA SALLE STREET TUNNEL—McCormick Waterproof Compound not only fulfilled all tests and requirements, but "subsequent tests show that resultin concrete has nearly one and a half times the crushing strengt of plain concrete of same proportions."



COALING STATIONS

Water Stations
Water Treating Plants
Boiler Washing Plants
Filtering Plants
Oil and Water Cranes
Sand Blast Outfits
Coal Hoists and Engines
Water Tanks and Towers
Gas, Gasoline and Oil Engines

T. W. SNOW CONSTRUCTION CO.

537 So. Dearborn St., Chicago, Ill.